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Halibut fishing on the Pacific Coast.

PROMOTING OUR SUPPLIES OF FOOD FISHES.—[See page 88.]

The Contributions of Geodesy to Geography*

By Determining the Size and Shape of the Earth

By William Bowie, Chief, Division of Geodesy, United States Coast and Geodetic Survey

The determination of the shape and size of the earth and the location of places on its surface, referred to selected fundamental planes, are the geodesist's principal contributions to geography.

The earliest geographers must have found it very difficult to carry on their operations, owing to lack of knowledge of the shape and size of the earth and of the true relative positions of the areas under investigation.

A very good value for the size of the earth was obtained from the measurement by triangulation of a meridional arc of about 8½ degrees extending north and south of Paris by Domenico and Jacques Cassini between the years 1683 and 1716.[1] But the fact that the earth's mean figure is an oblate spheroid was only discovered as a result of the observations made in Peru and in Lapland. This work was begun in 1735.[2]

The first near approach to the actual figure of the earth resulted from triangulation done in the last decades of the eighteenth century to connect the observatories of Paris and Greenwich and to determine the length of the earth's meridian quadrant. For the latter purpose an arc of the meridian of nearly ten degrees was measured in France. One ten-millionth of the resulting length was adopted as the standard of length (the meter). Any other length could have been selected, as standard for the meter bears no exact relation to a quadrant, as later and more accurate data show.[3]

Geodesists were very active during the nineteenth century, and will be for some time to come, in making geodetic measurements to determine the mean figure of the earth with greater and greater precision. There comes a time, for any given area, when it is useless to add more geodetic data for the purpose of obtaining a more nearly exact mean figure, for there are constant or systematic errors present in the data the effect of which is probably much greater than that of the accidental errors.

But there is much to be gained by extending geodetic surveys to new areas and especially to new continents. (By geodetic survey is meant, here, triangulation and observations at connected astronomic stations.) Nearly all of the values of the earth's figures now available are the result of geodetic measurements in the northern hemisphere, and the measurements in that hemisphere, from which the earth's figure has been derived, have been confined to India, Europe and the United States. We may hope to get, before long, values for the figure of the earth from geodetic operations in South America, Africa and Australia. It is expected that the mean figures resulting from accurate and extensive geodetic data in those continents will agree closely with the figures obtained from continents in the northern hemisphere. The geodetic surveys of the several nations on each continent should be connected and the reductions made on one spheroid and referred to a single initial position for each continent. Should this be done we shall be able eventually to compute a mean figure of the earth which will be of such great precision that it will satisfy the most exacting demands of science.

THE GEOID.

Coincident with the extension of geodetic surveys there will be carried on the computation of the geoid. The surface of the geoid is probably so complex in shape that the work necessary to define it will have to be continued long after the satisfactory spheroid has been determined.

The geoid may be defined as that surface which coincides with the surface of the sea at rest. We can imagine an extension into the continents of an intricate network of sea-level canals. Then the surface of the oceans and of the water in the canals would define the surface of the geoid. At some points, probably not exactly at the sea shore, the mean surface of the earth—the spheroid—would intersect the actual sea surface, the geoid. Under the coastal plains the geoid would be slightly above the spheroid, while under great mountain ranges the geoid would be far above the spheroid, possibly as much as one hundred meters. Over the oceans the geoid would be under the spheroid surface by amounts depending upon the depths of the water.

There is only one way to determine accurately the size of the earth, and that is by measurement on the continents of the lengths of arcs connecting points where the astronomic latitude and longitude have been determined. The measurements of such arcs may be direct, or they may be by means of triangulation. The earliest measurements were by the former method, but, with the introduction of accurately graduated circles and the application of wires in the eyepieces of telescopes, the indirect method came into general use.

At frequent intervals, in triangulation, the sides of some of the triangles in the scheme are accurately measured, in order to control the lengths. At the present time, this is done almost exclusively with nickel-steel (invar) tapes or wires. The probable accidental error of a measured length is seldom greater than about 1 in 1,000,000. The constant error in such a measurement may be as great as 1 in 300,000. This accuracy is, however, far greater than that of the lengths of the triangle sides, as computed through the chain of triangles. The uncertainty of any one line between bases is about 1 in 100,000, on an average. A long arc, say one across a continent, can be measured with greater accuracy than that, for even the systematic and constant errors of the various sections of the arc would probably act as accidental errors and the greater portion of their effect would be eliminated.

The observations for latitude, longitude and azimuth, or direction, are made on the stars; and in the most refined work a correction is made for the variation of the pole.

One might think that the determination of the figure and size of the earth is a very simple process, consisting merely of obtaining by accurate observations the accurate astronomic latitudes of several points on a meridian and then measuring accurately the linear distances between them. Three such points being sufficient to obtain the equation of the ellipse formed by the intersection of the meridional plane and the spheroid, the shape and size of the earth would be known. This would be true if the spheroid and the geoid coincided throughout, but, as stated above, they do not do so. The plumb line, to which all astronomic observations are referred, is, at each point, normal to the geoid, which is a very irregular surface, and, therefore, very many astronomic stations must be established and used. The greater part of each of the differences between the observed astronomic position and the position referred to an adopted smooth mean surface, must be treated as an accidental error in the computation of the figure of the earth. These differences, called deflections of the vertical, also station errors, reach a maximum value of about twenty-five seconds of arc (within the area of the United States), which is nearly one half mile. In the island of Porto Rico, the relative deflection between two astronomic stations, one at Ponce and the other at San Juan, was fifty-six seconds of arc, or about one mile.

The shape, but not the size, of the earth may be determined from the observed value of gravity at stations widely distributed in latitude. But here again a few stations are not sufficient, for the change in the value of gravity with the latitude and with the elevation above sea level does not exactly follow any regular law, owing to the disturbing influences of masses above sea level and the deficiency of mass in the oceans.

It is evident that the difference between the theoretical and the observed values of gravity and the deflections of the plumb line (which, as stated above, are the differences between the observed and the theoretical astronomic positions) are due to the disturbing influences of the topography and the effect of deviations from the normal densities in the earth's crust. The term "topography" is applied to the visible land masses and the deficiency of mass in the oceans. But, even when the attractions of the topography are applied as corrections, the differences, which may still be large, would be generally of the opposite sign.

ISOSTASY.

About sixty years ago, Archdeacon Pratt of Calcutta arrived at the conclusion, from a study of the deflections in India, that there must be a deficiency of mass under the Himalaya Mountains and that the deficiency extended to a limited depth.[4] The announcement of this theory marked an epoch in geodesy. From time to time, writers in different countries have elaborated on the mere statement of Pratt.[5] But it was Hayford who gave this theory a quantitative expression when, as a member of the U. S. Coast and Geodetic Survey, he corrected the astronomic latitudes, longitudes and azimuths in the United States for the effect of topography and its negative equivalent, called "isostatic compensation," when making two determinations of the figure of the earth.[6]

Several reports by the Coast and Geodetic Survey give the results of investigations based upon the subject of isostasy,[7] and a number of other articles have appeared in recent years, notably those by Dutton, Helmert, Barrell, Becker, Hecker and Gilbert.[8]

If the earth were composed of homogeneous material, or if at all points at any given depth the density were the same, the earth's surface, due to its own rotation and the force of gravitation, would be very nearly a true ellipsoid of revolution. These conditions as to the distribution of density do not apply universally. The earth's surface is very irregular, as is shown by the existence of continents and oceans.

Geodetic observations and their discussion show conclusively that the continents and oceans are not held in place by the strength of the earth's crust but exist and are maintained by a deficiency and excess of density, respectively, under them in the outer portions of the earth's volume. The investigations of the Survey show that at all places at a depth of about 120 kilometers (75 miles) below sea level there is an approximate condition of equilibrium as to pressures. This condition of approximate equilibrium has been given the name of *isostasy*. It has been proved by recent investigations that the area of the United States as a whole is in a state of isostasy to a very high degree of completeness. Whether small sections of this area are in such a condition must be a subject for further research. The extent of an area for which the topography may not be compensated is a question which should be solved as soon as practicable, for the result will be of great value to many branches of science.

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*From the *Geographical Review*.

[1]These operations are described by the younger Cassini, Jacques, in the *Mémoires de l'Académie Royale des Sciences*, "De la grandeur de la terre et de sa figure," Paris, 1718, and in another work, "Traité de la grandeur et de la figure de la terre," Paris, 1720, and Amsterdam, 1723.

[2]Pierre-Louis-Moreau de Maupertuis: La figure de la terre déterminée par Messieurs de l'Académie Royale des Sciences qui ont mesuré le degré du méridien au cercle polaire, *Mémoires de l'Académie Royale des Sciences*, Paris, 1737. Pierre Bouguer: La figure de la terre déterminée par les observations de Messieurs Bouguer et de la Condamine de l'Académie Royale des Sciences, envoyés par ordre du Roy au Pérou, pour observer aux environs de l'Equateur, Paris, 1749. Charles Marie de la Condamine: Mesure des trois premier degrés du meridién dans l'hémisphére austral tirée des observations de Mrs. de l'Académie Royale des Sciences, envoyés par le Roi sous l'Equateur, Paris, 1751.

[3]Modern measures give the length of a quadrant of a meridian greater by about 2,000 meters than the intended 10,000,000 meters.

[4]John Henry Pratt: On the Deflection of the Plumb-line in India, caused by the attraction of the Himalaya Mountains and of the elevated regions beyond; and its modification by the compensating effect of a deficiency of matter below the mountain mass; also, On the Influence of the Ocean on the Plumb-line in India, *Philos. Trans.*, vol. 149, 1859, London.

[5]A. R. Clarke: Geodesy, pp. 96 and 350. H. A. Faye: Sur la réduction des observations du pendule au niveau de la mer, *Comptes-Rendus de l'Acad. des. Sci.*, vol. 90, 1880, Paris.

[6]J. F. Hayford: The Figure of the Earth and Isostasy from Measurements in the United States, U. S. Coast and Geodetic Survey, Washington, 1909; *idem:* Supplementary Investigation in 1909 of the Figure of the Earth and Isostasy, U. S. Coast and Geodetic Survey, 1910.

[7]In addition to the two mentioned in the preceding footnote: O. H. Tittmann and J. F. Hayford: Geodetic Operations in the United States, 1903-06, U. S. Coast and Geodetic Survey, 1906; J. F. Hayford and William Bowie: The Effect of Topography and Isostatic Compensation upon the Intensity of Gravity, *U. S. Coast and Geodetic Surv. Special Publ.* No. 10, 1912; William Bowie: Effect of Topography and Isostatic Compensation upon the Intensity of Gravity (Second Paper), *U. S. Coast and Geodetic Surv. Special Publ. No.* 12, 1912.

[8]C. E. Dutton: On Some of the Greater Problems of Physical Geology, *Bull. Philos. Soc. of Washington*, vol. 11, 1888-91, pp. 51-64.

R. F. Helmert: Die Schwerkraft und die Massenverteilungen der Erde, in "Encyclopädie der Mathematischen Wissenschaften," Band VI, 1 B, Heft 2, Leipzig; Unvollkommenheiten in Gleichgewichtszustande der Erdkruste, *Sitzungsber. der Kgl. Preussischen Akad. der Wiss.*, vol. 44, 1908, Berlin.

Joseph Barrell: The Strength of the Earth's Crust (a series of articles), *Journ. of Geol.*, vols. 22 and 23, 1914 and 1915.

G. F. Becker: Isostasy and Radio-activity, *Bull. Geol. Soc. of America*, vol. 26, 1915, pp. 171-204.

Oskar Hecker: Bestimmung der Schwerkraft auf dem Atlantischen Ozean, sowie in Rio de Janeiro, Lissabon und Madrid, Kgl. Preussiches geodät. Instit, Berlin, 1903; Bestimmung der Schwerkraft auf dem Schwarzen Meere und an dessen Küste, sowie neue Ausgleichung der Schwerkraftsmessungen auf dem Atlantischen, Indischen, und Grossen Ozean, Zentralbureau der Internationalen Erdmessung, Berlin, 1910.

G. K. Gilbert: Interpretation of Anomalies of Gravity, *U. S. Geol. Surv. Prof. Paper 85-C*, 1913.

The question may be raised, Why should a geodesist be interested in the question of the variations in the density of the materials in the earth's crust? The answer is that a knowledge of the variations of density enables him to apply corrections to the deflection of the plumb line and the observed values of the intensity of gravity, and thus obtain from the results very much more accurate values for the earth's figure.

While isostasy has been from the first a subject of great importance to the geodesist, it has become an even greater one to the geologist and seismologist. Many geologic hypotheses and theories must be modified to conform to the facts deduced from the results as to the variations of density in the outer portion of the earth, obtained from geodetic observations.

TRIANGULATION.

Thus far we have considered only the value of geodetic measurements in connection with the determination of the figure of the earth. They have also a very practical and immediate value in determining the positions of the topographic features with relation to the fundamental planes. The generally adopted system of co-ordinates is spherical and is referred to the plane of the equator for latitudes, the plane of the meridian through the observatory at Greenwich, England, for longitude, and the mean sea surface for elevation.

Owing to the station errors or deflections of the vertical at astronomic stations it is not possible to obtain the correct relative position of different places on the earth's surface by astronomic observations alone. This was strikingly shown in Porto Rico. The Spanish charts of this island were based upon astronomical stations at San Juan and Ponce on the northern and southern sides of the island, respectively. When the United States became the possessor of this island, it was decided that a strong triangulation should be carried across the island from San Juan to Ponce, as the fundamental control from which new surveys should expand. The distance between the two places by triangulation was found to be about one mile shorter than the distance given by the two astronomic determinations. The triangulation across the island is subject to an actual error not greater than ten meters as a maximum.

The trouble was at the astronomic stations but was not due to errors in the observations. There was a relative deflection of the vertical of about fifty-six degrees of arc, due to the attraction of the island mass and the repelling force, or what might be called a lack of attraction, of the vast volumes of the Atlantic Ocean to the north and the Caribbean Sea to the south.

The same phenomenon has been observed in the interior of the United States, where there are astronomic stations short distances apart and on opposite sides of a large mountain range.

It is evident from the above that an accurate map cannot be made over a large area where each of the separate sections is based on the astronomic position of the starting point of each of the various surveys. There will be overlaps and gaps which cannot be adjusted in a satisfactory manner. This difficulty is overcome by making a triangulation ahead of the surveys, for the connected scheme of triangulation will give the correct relative positions of the several stations. To obtain the most probable absolute positions on the earth's surface of these stations a mean position for latitude and longitude is obtained by connecting into the triangulation scheme many astronomic stations. It is assumed that in a large area there are as many positive as negative deflections, and for a country the size of the United States this is very nearly true.

In the United States a mean astronomic position was adopted in 1901 and called the United States Standard Datum. Several years ago this datum was also adopted by Canada and by Mexico and then its designation was changed to that of the *North American Datum*. The triangulation of Alaska will soon be connected to that of the United States and Canada and then maps of its area will also be based on the continental datum. When the whole mapped areas of Alaska, Canada, the United States and Mexico are based upon a connected scheme of triangulation, which will no doubt be done within the next few decades, this continent will be in a very enviable position, as far as control of maps is concerned. It should be said here that for the control of large areas, triangulation of the highest order must be extended in a network of long arcs. Lower-grade triangulation can be used to fill in the intermediate areas for the immediate control of the detailed topographic surveying and the map making.

PRECISE LEVELING.

In nearly all geographic work a knowledge of the elevation of the area under investigation is also necessary.

In rough work, such as topographic reconnaissance and exploration, the barometer (mercurial or aneroid) gives results which are satisfactory; in fact, this is the only instrument adapted to such work. But the atmospheric pressure at any given place is so variable that the elevations obtained with the barometer are much in error, even when readings are made simultaneously at base stations, unless the line of base stations is carried along in very short steps.

For all accurate topographic work it is necessary to have leveling done with the eye or spirit level. This instrument and the results obtained with it are, no doubt, familiar to the reader. There are many such instruments in use, but the types of most interest to us are what are termed precise levels. With these, lines of levels may be extended thousands of miles with no appreciable error so far as the purposes of geography are concerned.

Eighty-three per cent of the precise leveling done in the United States has errors of closures of circuit which are not more than 1.57 thousandths of a foot per mile. As the precise level net is made up of many circuits, it is reasonably certain that the absolute error in the elevation of any precise level bench mark in the interior of this country is not more than one and one half feet and the probable error is considerably less than that. It is necessary to cover the country with a network of precise leveling in order that errors of the elevations carried inland may not accumulate to a troublesome extent. This is readily understood when we consider the great distances from the coasts of this country to interior places. The error in ordinary leveling between any two contiguous bench marks might be small, but, when such leveling is carried from the Atlantic to a point in Minnesota, for instance, and to the same point from the Pacific Coast, the difference between the two elevations obtained for the same point might be many feet. Such an error would be a source of great confusion to the surveyor and map maker.

We have seen that the province of geodesy in geography is to furnish the correct dimensions of the earth, to determine approximately the distribution of material in the outer portions of the earth, and to furnish the correct positions and elevations on the earth's surface of the starting points for surveys and maps. Realizing the great importance of geodetic surveys and investigations, nearly all of the nations of the world have organizations for the purpose of carrying on this work; and to co-ordinate the results and to undertake the international phases of this important subject there is an International Geodetic Association, in which more than twenty nations are represented.

Briquetting and Tar Distilling Plant at Nuremberg Gasworks

COKE breeze and pitch dust are incorporated in a mixer heated by superheated steam at 200 deg. Cent. and the mixture treated in a rotary press; 8 per cent of hard pitch is used and the crushing strength of the oval briquettes averages 80 kilogrammes (1,137 pounds) per square inch. The strength of the briquettes depends chiefly on three factors, viz.: the proportion of binding material; the description or softness of the pitch used; and the pressure (15 tons) which the outer edges of the two rollers exert on one another. The proportion of pitch added cannot be varied much, because if it is too low the briquettes lack solidity or strength, and if it is too high they stick in the mold. The resistance of the briquettes to pressure in the direction of the small axis of the oval is tested by a very simple apparatus. A piston working in a short cylinder is of such a size that, at 9 atmospheres, it exerts a pressure of 120 kilogrammes. The briquette resting on a plate is compressed by the piston. The cylinder is connected with the steam pipe, so that only condensed water passes under the piston. When the steam valve is slowly opened, the pressure, read on a gage, gradually rises until a small jerk shows that the briquette has been crushed. The briquettes are suitable for steam boilers or household purposes. They now serve as fuel for the whole of the boilers on the works, and a considerable quantity remains over for sale. The boilers produce more steam in a given time, and require less attendance and cleaning, and less dust is produced. Excluding cost of material, the cost of manufacturing is only 30 pfennigs per 100 kilogrammes briquettes (3 shillings per ton). In the Nuremberg gasworks the pitch required for making the briquettes is about double the quantity of retort pitch produced; the balance is obtained from the tar plant which splits up the tar into hard pitch, light oil (up to 170 deg. Cent.), and heavy oil (up to 360 deg. Cent.).—*Note in J. Chem. Ind. from an article by R. Terhaest in J. Gasbeleucht.*

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

EDITOR, SCIENTIFIC AMERICAN SUPPLEMENT:

In No. 2127, of October 7th, 1916, I have read an article on "The Propagation of Sound by the Atmosphere." Speaking of Dr. Van Everdingen's investigations, it says: "It would seem desirable, however, to continue and extend them."

On the 1st of November, 1916, there was a naval battle between the English and German navies, called the "Coronel" battle. Although it was on the ocean at 80 or 100 miles from this port, latitude 36 degrees 30 minutes south and longitude 75 degrees 30 minutes west (this is an approximate situation, for I have no exact data), the cannon shots were not heard on the coast of Chile, nor in the nearby lighthouses, nor in the cities farther in the interior; but at a distance of 190 miles, at the foot of the Andes, from the department of Parral up to that of Yungay, from the 36 degree latitude up to 37 degrees, and following more or less the space between 71 degrees 20 minutes and 71 degrees 40 minutes at Parral and a little more toward the west of Yungay, they were distinctly audible. At several intermediate points nothing was heard. At this plantation, Villa Rosa, the shots were perfectly heard; being a holy day, all the employees talked about their direction. Several of them had been in military service in artillery batteries, and the writer was lieutenant in the Chilean Navy, consequently the sounds of the shots could not be confounded with anything else. Besides the hour was easy to be verified, the battle being at sunset.

IGNACIO URRUTIA MANZANO.

EDITOR, SCIENTIFIC AMERICAN SUPPLEMENT:

In looking over a back number of the SCIENTIFIC AMERICAN SUPPLEMENT of date of March 25th, 1916, page 197, I came across an article headed, "Prevention of Rust by Painting." As I have spent more years in the study of the wear of paint than Liebruch and Spitzer state they spent days, and as my observations showed me that more coats (up to four) of the *right kind* of paint made a better protection against rust than fewer coats, I shall be much interested to know what kind of material Liebruch and Spitzer used in their test and what time was given between coats.

EDWARD C. SHERMAN.

Walnuts in Asia, etc.

THE question has come up lately as to the probable competition which the French walnuts will likely have to stand in America from the California nut as well as the products from various parts of Asia. This refers to the thin shelled nut known usually as English walnut. Regarding the exportation from Asia, Messrs. M. & L. Rigotard state that eastern China and Persia are the principal exporters. They speak of two varieties which they received from Tientsin, one of which is round and does not possess the usual folds of a woody nature in the interior of the kernel, and hence it is much easier to extract the kernel from the nut. There are two varieties, the round and the long. As a comparison, the French table nut weighs 11 grammes on the average and yields 42 per cent by weight of kernel. The Tientsin round nut weighs 12.3 grammes and has about the same yield of kernel, while the long variety weighs 12.4 grammes, in which the kernel figures for 48 per cent, but in this case the woody parts penetrate so closely into the kernel that it can hardly be removed. For this reason the long variety is not likely to come upon the market. There are relatively few walnut trees in Shanghai, Corea or Manchuria. As regards central China, it cannot export this product economically. The Cashmere region of India grows only the hard variety of walnut, but in Persia there are found numerous types of walnut trees, especially in the district of Azerbäidjan, which is said to export over ten tons of kernels per annum. As to the round Chinese variety which we mentioned, it is thin shelled and the halves come apart easily. Weight is only 9.3 grammes, but it yields as much as 57.6 per cent of kernel, and this latter is rich in nitrogenous products (17 per cent) as well as in oil (67 per cent). However, its taste is not very agreeable. The long or egg-shaped kind is also small, and it has a thick shell which it is difficult to open. The authors remark that a certain quantity of Persian walnuts are shipped by way of the Caspian Sea to Trieste or Marseilles.

Anomalies in the Animal World

Flying Mammals; Flightless Birds and Other Curious Forms

By B. W. Shufeldt, M. D.

INTRODUCTION.

BIOLOGICAL science presents us with no question for discussion that carries with it a greater amount of interest than the one having reference to what constitutes an abnormality, or even an anomaly, in nature. By nature is meant the existing life of the animal and vegetable kingdoms as we find it in the world at the present time.

Many use the terms "abnormal" and "anomalous" as though they were synonymous ones, and to this some lexicons form no exception. As a matter of fact, an "abnormality" and an "anomaly" in the case of any animal or plant, may mean, and usually do, essentially two quite different things or conditions. To fix exactly what is meant by any living thing being abnormal, it is obvious that we know what constitutes, in all particulars, the normal in the case of the form to which the term is applied. Again, a character or a condition may, at the same time, be both abnormal and anomalous, the two being frequently associated.

If we select, by way of illustration, an example from our own species, it may be said that a normal man is an individual whose system and organization is completely free of disease in all particulars; who presents the average proportions with respect to figure and height; the organs of whose body are performing, at all times, their natural and particular functions; whose appendicular structures are present in due amount, number and proportions, as the teeth, the nails, the hair, and the rest. All the senses, as sight, hearing, touch, taste, and so on, are perfect, and this state also exists with respect to the mental and psychical functions of his organization; indeed, this man must, in all particulars, be the ideal perfect being, in order to meet what is implied by the term normal. So rare is this state that there are those who contend it is never to be found in nature; and certain conditions which are generally regarded as abnormal are, as a matter of fact, normal. For example, how often do we meet with men past fifty years of age possessing a perfect set of teeth? So some physicians contend that caries of the teeth is a mere evidence, among many others, indicative of advancing age in man, and to have a sound set of teeth at that time of life is an abnormal condition. Many similar instances of this, with respect to other structures, might be cited.

But to be born with teeth, or to have the heart on the right side instead of on the left, or ligatured twins (Siamese) are, with hundreds of other states, all abnormal conditions, and all, it may be said, anomalous as well. The anomalies in nature refer more particularly to the *unusual* or to what does not commonly occur. We find a flightless cormorant, for example, and it cannot fly for the reason that its wings have aborted. Now this is an anomalous condition, for it is by no means usual; but it is not, strictly speaking, abnormal, for the reason that what led to this bird losing its power of flight was perfectly normal in nature, and consequently the result was normal. New species, genera and families in nature are produced by certain environmental changes or by various other causes and achievements, all being entirely normal in nature, and as a consequence the resultants are normal. So we have such a bird as Harris' Cormorant placed in a *new genus* and given a specific name. The same would have happened had a new species of bird *with perfect flight* been discovered. It is not anomalous for a bird to gradually lose its power of flight through a number of generations of descendants, and it is quite normal that it so happens under certain conditions. The ancestors of the Great Auk were undoubtedly birds of flight; but flight was not especially useful to the species or even essential. Therefore it was gradually and normally lost in the descendants.

Many unthinking people speak of the anomalous or the abnormal in nature as "freak forms," but there are none such, and it is merely a term to veil their ignorance as to the causes for such departures from the usual and the normal.

Endless, indeed, are the instances in nature of the abnormal and the anomalous, the mere naming of which would furnish material for a library of no mean proportions. Instances enough have been cited here for present purposes—enough, it is hoped, to make the distinction clear.

Mankind presents, in all parts of the world and in all planes of society, as many and as striking abnormalities and anomalies as any other assemblage of forms in existence. The departures from the normal and the usual in men, women and children are quite similar in character to what we find among other animals, and, if anything, they are even more frequent. History furnishes many examples of people who have been more hairy than chimpanzees, and still others with far less intelligence than those simians. There have been no end of human giants and dwarfs among the various races of the earth, while albinoes occur quite as often among us as among other creatures. This is equally true with respect to polydactylous hands and feet, aborted limbs, ligatured twins, teratological specimens, and so on to the end of the category. With respect to his mentality, man exhibits a far greater number of departures from the normal in his psychoses and neuroses than all the rest of the animal world combined.

Fig. 1.—Brown bat (Eptesicus fuscus, male), of the Eastern United States, in the act of crawling on the level surface.

Fig. 2.—Brown bat hanging by hind feet from broken limb; same animal as in Fig. 1.

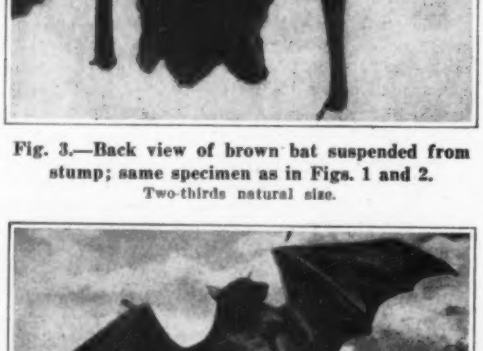


Fig. 3.—Back view of brown bat suspended from stump; same specimen as in Figs. 1 and 2.
Two-thirds natural size.

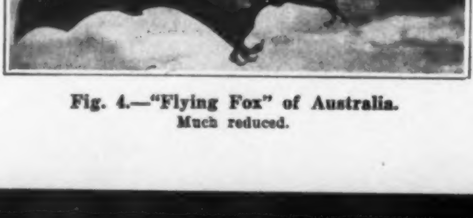


Fig. 4.—"Flying Fox" of Australia.
Much reduced.

Most mammals are terrestrial or arboreal by nature, and bring forth and rear their young in a manner well known to any intelligent reader. Wide departures from this rule constitute anomalies, and they are not far to seek. Such marine mammals as whales, porpoises and their congeners are familiar examples, while such animals as the dugong and the manatees furnish us with still others. Egg-laying mammals, however, and those that can fly far better than many birds so endowed, and those possessing a protective armor, are the most extraordinary species, and these are more or less fully described in this series of articles.

For similar reasons, flightless birds, one of the most pronounced anomalies in this group, have been selected for description rather than those exhibiting any other known peculiarities, of which there are by no means a paucity.

As we leave birds to pass to the reptiles and batrachians, and from them to fishes, into the unlimited host composing the great world of the invertebrata below them, of which alone over 300,000 different kinds of insects are already known, it becomes more and more difficult—in the different groups as we descend the scale—to define, in any one of them, what may really be considered to be normal, ordinary or usual. It would require several volumes to do even scant justice to such a rich field for research.

There is a tremendous gap between the common perch—which may be taken as a type of the most ordinary fish—and many of the extraordinary species we have taken from the great depths of the ocean—sometimes well on to a mile below the surface. And so might be presented similar illustrations from the other great classes of animals.

For our present purpose it has been found necessary to select only some of the least known and most remarkable anomalies among a restricted few of the remaining groups to be noticed. It is hoped, however, that such as these are, they will be found both interesting and instructive, and perhaps calculated to inspire further research on the part of the reader, either in the libraries or, what is far better, in actual observation in the realm of nature.

It will not be necessary to acknowledge here drawings or other assistance, as this will be done very fully in the proper places in the articles. It has been one of my objects to set forth how far-reaching the interest in this subject has been among the world's naturalists; while, upon the other hand, it is believed that these articles as a whole will be found to be, to a large degree, *sui generis*.

BATS. MAMMALS POSSESSING THE POWER OF FLIGHT IN THE HIGHEST DEGREE. VARIOUS KINDS OF BATS, WITH OBSERVATIONS ON THEIR HABITS.

When it is desired to characterize unusual power in the matter of aerial locomotion, how frequently do we hear the comparison made that it—whatever the thing or creature may be—"flies like a bird," or it did or can fly like a bird, and so on. Such expressions occur in various languages all over the world, and it is almost a universal notion to consider birds as being *ne plus ultra* in this question of flight.

Whoever thinks of comparing any of our "flying" devices, or any animal not bird, with such volant capacity as the *bats possess*, making such comparisons with the intent of conveying superiority in the achievement? No one. When we come to really think seriously about this flight of birds, some curious facts assert them-

selves with great force and promptness. In the first place, we have, in various parts of the world and representing divers families of birds, some that cannot fly at all, such, for example, as ostriches, kiwis, and their congeners; others possess but very limited powers of flight, as certain species of parrots, rails, and others. Now a teal duck can fly with extraordinary power and rapidity, for it has been estimated that it can thus proceed at the rate of between eighty and ninety miles per hour. However, for the most part it is like the flight of a bullet and with no more variation to it. Variation only occurs occasionally and chiefly at the stages of commencing and terminating its flight.

A perfect host of all sorts of species of birds in the world are very indifferent fliers, and they accomplish their migrations sometimes through a species of feeble flight, in no way associated with the idea of power or variety. Most of the flight of our aeroplanes is after the order of some of the swift-flying ducks, or the sailing flight of various partridges, quails, or their kind.

Humming-birds, which are, by the way, confined to

Fig. 5.—Australian fruit bat or "Flying Fox." Usual way of suspending itself when at rest.

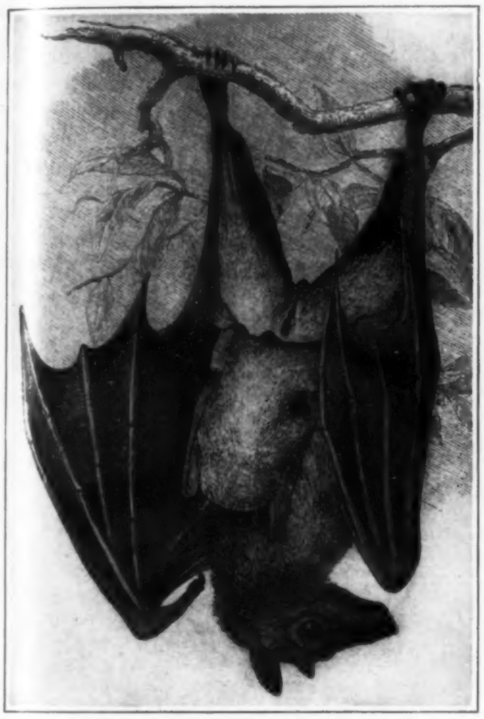


Fig. 6.—South African collared fruit bat and young (Cynonycteris collaris); female.

Much reduced. Photo by the author of Fig. 13 of "List of Animals," Zoölogical Society, London, 1896. See also P. Z. S., 1870, p. 127.

Fig. 7.—Thomas's fruit bat (Pteropus notalis); female; from Christmas Island.

Photo by the author of colored plate XLI, P. Z. S., 1887, p. 511. A large, almost black species.

the Western Hemisphere, perhaps stand among the most powerful fliers of the world's existing avifauna; moreover, their flight is extremely varied and characteristic of the group, being entirely different from that of the birds we call swifts—a family with which the vast majority of present-day ornithologists associate them.

So much for bird-flight; and with due consideration for all of its varied kinds, there is no single bird, apart from its possessing great power of flight in a *straight line* or in a more or less curved one, that can, in any way, compare with the remarkable flying accomplishments of any of the smaller bats of the world or, presumably, with the big ones either.

Take our common little Brown bat of the Eastern United States, for example (Figs. 1 to 3); there is no bird of its size that can possibly equal it with respect to its performances in the air. To be sure, the best of these are to be observed during the hour of twilight; sometimes during moonlit nights, or even at early dawn. This is not to be taken into consideration, however, for the animal is a nocturnal one by habit, although there are times when it may be seen abroad during the very middle of the day, with the sun shining at its best; this is a rare occurrence, however.

Our brown bat cannot fly with the rapidity or the power of a teal duck, though it may, under proper conditions, sustain a flight which for swiftness is quite coequal with that of any of the medium-sized passerine birds, such, for example, as robins or marsh blackbirds. To study the capacity of one of these aerial acrobats at its best is to observe the volant gymnastics it performs when in quest of its evening meal, which it finds in the host of nocturnal insects, as these maneuver meaninglessly in the glare of a street arc-light. No bird living can, in flight, in any way equal its movements upon such occasions; in its efforts to seize its prey, this little winged entomologist of the air shoots about, tumbles and twists, darts hither and thither, flits in beautiful curves, all the way from any of those known to the geometrician, to others, nearly straight in their course. Every once in a while we hear the snap of its tiny jaws as its seizes some hopelessly helpless insect, utterly lacking in any means of defence against such a well equipped and expert predatory athlete, whose movements, though apparently erratic, are, as a matter of fact, made with the greatest possible accuracy for the attainment of their purpose.

When a June-bug, or some coleopteran of similar size, seizes his fancy as a top-off for his evening repast, what does he do but make after one in a straight course, and, as he overtakes his quarry, he so controls his movements that he is enabled to adroitly capture it in the concavity formed by the membraneous interfemoral apron stretching between his hinder pair of limbs. Instantly, upon the accomplishment of this feat, he bends forward and seizes the hapless insect with

Fig. 8.—Giant fruit bat (P. grandis, male), from Solomon Islands.

Photo by the author of colored plate in P. Z. S. (Pl. xxv); much reduced. The specimen in front is represented as hanging by its thumb, and the one behind by its feet.

his extremely sharp little teeth, and devours it as best he may.

A bat's superiority in flight is occasionally to be observed in another way; for, if one be shut up in a room, it is wonderful to note the accuracy and beauty of its flight as it flits about in all directions, in its endeavor to find some opening through which it may escape. It will alight with ease wherever it pleases; it will shoot into some small crevice to hide itself away, or suddenly dart through the slats of a window-blind and make good its escape. What is most marvelous of all, it never upsets anything, no matter how much delicate bric-a-brac may be arrayed upon the mantel-shelf or elsewhere. A sparrow or any other small bird, endeavoring to find an exit under the same circumstances, flies around in the most insane manner possible, bumping against window-panes, knocking over small objects on the shelves, and sometimes almost braining itself against the wall or some piece of the heavier furniture in its efforts to escape.

So thoroughly has the entire anatomical structure of any one of these interesting little mammals become adapted to the requirements of its life in the air that they are, of all animals, says Flower, "the least terrestrial, not one of them being equally well fitted, as most birds and insects are, for progression on the earth. This is due to the hind as well as the fore limbs, being pressed into the service of aerial locomotion. The hind limb is so well rotated outward by the wing-membrane that, contrary to what obtains in all other vertebrates, the knee is directed backward, and corresponds in position to its serial homologue the elbow. When placed on the ground, therefore, the

Fig. 9.—Woodford's fruit bat (Nesonycteris woodfordi), from Fauro Island.

Body fulvous-yellow, wings black. Photo by the author of plate xxvi, P. Z. S., 1887.

animal rests on all fours, having the knees directed upward like a grasshopper, while, in order to bring the foot into a position for forward progression, it is rotated forward and inward at the ankle. Walking under these circumstances is at best only a species of shuffle, and that this is fully recognized by the animal is evidenced by its great anxiety to take to the wing, or, if this be impossible, to ascend to some point where it can hitch itself up by the claws of the hind-legs in its usual position when at rest." (See Figs. 1 to 3; also "Brit. Encylo." Art. "Mammalia," vol. xv., p. 406.)

Bats of most curious form, and of a great variety of sizes and species, are found in nearly all parts of the world; while their fossil remains extend as far back as the Upper Eocene in this country and on the Continent. There can be no question but what the very remote ancestors of bats were mammals of a strictly terrestrial type; that it is probable they subsequently became arboreal in habit, then long leapers from limb to limb, which in time demanded lateral, parachutal expansions to sustain them in such flights—whence the dermo-membranous developments between the fore and hind limb upon either side, such as is now to be observed in the case of flying-squirrels and the cobego (see descriptions beyond).

In bats and "flying-foxes," however, these skin-membranes came to be stretched between the enormously developed fingers and unduly elongated bones of the forearms, and, to some extent, the arm-bones (*humeri*). In our bat illustrations (Figs. 1 to 3) these membranes are almost completely folded up; but they are well shown in the case of the "flying-fox" in Fig. 4—an animal related to the true bats, but with very different habits, as will be shown in the next article.

These last-named, most interesting mammals possess, together with the bats, true *wings;* their flight, as pointed out above, is more perfect than that of birds. It may be said here that they are the only true *flying* mammals known at the present time.

The so-called "flying" squirrels, phalangers, cobego, etc., do not fly, neither have they true wings; they simply perform a *sailing* flight after once springing into the air. We see the difference in such machines as a parachute (cobego) and any of the aeromotors or aeroplanes—the former, with its sustaining surface once spread, can but *sail* to its destination; while an aeromotor flies there and even *changes its direction and destination in the air* at the will of the operator.

Bats' wing-like hands, including those of the fruit-bats (*Pteropuso*), are unique in nature at the present time. Several extinct fossil forms were similarly endowed, but they do not fall within the scope of this article to treat.

These wings of bats are extremely sensitive with respect to the sense of touch; and some species of these animals have enormous ears, and extraordinary skin-developments about the nose and face, which are all likewise very sensitive—the whole enabling these animals to avoid things in their way and recognize objects within touch. This is important to bats; for, although their minute eyes are very keen, some of the species are actually blind. It is only the latter that merit the expression "as blind as a bat."

Some bats perform long seasonal migrations; but the majority of the northern species of both hemispheres hibernate. These habits account fully for the wide distribution of the order—some being found as far north as the Arctic Circle. However, so far no bats have been found on certain of the world's islands, as the island of St. Helena, Kerguelen Island and the Galapagos Islands.

In his very excellent work, a "List of North American Land Mammals in the United States National Museum, 1911" (Pub. U. S. Nat. Mus. Bull. 79, 1912), Mr. Gerrit S. Miller, Jr., curator of the Division of Mammals of that institution, divides the order of bats (*Chiroptera*) in eight families, and these into *seventy-one genera*—the group in North America, according to this eminent authority, numbering some 216 species and subspecies; these include the "leaf-nosed bats," vampires, and other large forms.

The largest and rarest of all our bats in the Northern and Middle States is the hoary bat; while the little and the large brown bat, the silver-haired bat and the red bat, among one or two other species, are quite abundant in various districts.

Bats generally have but one or two young at a time, and they are tiny, hairless little things when they are born; but they take at once to the hair of the mother's breasts, which are situated well up on her chest, as in the case of our species. Here they cling with great tenacity, and she, in the meanwhile, flies about as usual. It is said that she will sometimes leave her young on the limb of a tree or other convenient place, and forage about for herself for a while. When the young are older, she probably brings them food on such occasions.

These interesting little mammals show no fear of man; on the other hand, they most frequently select places in his habitations wherein to hide during the day, and to breed, when that time arrives.

It has long been known that the "service which they render to vegetation by the destruction of insects, which in the larva state prey upon it, is very considerable, even in temperate climates. Some of the hot countries, in which these swarm by myriads, could not, but for them, be inhabited. In humid places, on the margins of tropical forests, mosquitos are troublesome enough as it is, but if the bats did not reduce their numbers, they would be utterly unbearable."

Before closing this article, and returning for the moment to the matter of flight among these smaller species of bats, it may be as well to record the experiments of Spallanzani, who "suspended willow rods in a room in which he turned loose some bats which he had blinded; but though he frequently shifted these, so as to make the passage between them as varied and as intricate as possible, these creatures never struck against one of them, though they kept flying about in all directions." The same experiments have been made by others with a similar result.

The literature referring to these small bats of the Northern States of the United States is very extensive, and much has been written about bats of all species by naturalists all over the world for many centuries past. In some parts of England these small bats are called "flitter-mice;" in France, "bald-mice" (*chauve-souris*); while in Germany the people also call them "flitter-mice" (*fleder-mäuse*).

In the South Atlantic and Gulf States we meet with a small bat wherein the tail is free, that is, it is not included in the membrane stretched between the hind limbs as in other species; this species has been called the Florida free-tailed bat (*Nyctinomus cynocephalus*). In still other species the tail has become an instrument of prehension, and is brought into play with the hind feet when the animal suspends itself.

Passing to the larger forms of the *Chiroptera*, we meet with a very numerous assemblage of flying mammals that easily take a high place among the most extraordinary creatures in the world; they all possess canine teeth; enjoy the power of flight in the highest degree; are found principally in the tropics of both hemispheres, and feed on insects, small vertebrates, fruit of many kinds, while some suck the blood of other animals, which is the case of the vampires of South America, where horses are the most usual victims. Blythe says that in India the megaderms (a large, big-eared bat) may be heard on quiet evenings crunching the heads and bones of frogs.

The *leaf-nosed bats*, with the remarkable and variously formed appendages on their noses, have already been referred to on a previous page; they occur in parts of Southern Africa and in Australia, Persia, Java, and other countries. They are big bats, and of them Sir William Flower said: "From whatever point of view the *Rhinolophidæ* may be considered, they are evidently the most highly organized of insectivorous bats. In them the osseous and cutaneous systems reach the most perfect development. Compared with theirs, the bones of the extremities and the volar membranes of other bats appear coarsely formed, and even their teeth seem less perfectly fitted to crush the hard bodies of insects. The very complicated nasal appendages, which evidently act as very delicate organs of special perception, here reach their highest development, and the differences in their form afford valuable characters in the discrimination of the species, which resemble one another very closely in dentition and in the color of the fur."

Then there are the "javelin bats," the "vampires," and the bats with long, extensile tongues; others with suctorial, circular disks on certain parts of the extremities. *T. tricolor* from Brazil possesses these organs, and they "have the appearance of small, circular, pedunculated, hollow disks, resembling in miniature the sucking cups of cuttle-fishes, and attached to the inferior surfaces of the thumbs and soles of the feet, with which the animal is enabled to maintain its hold when creeping over smooth, vertical surfaces." (Flower.)

Turning for a moment to the "fruit bats"—some species of which are so large that they have been called "flying foxes"—we meet with the giants of the Order. For example, the Kalong or Malay fox bat measures no less than five feet from tip to tip of its fully outstretched wings.

Then there is the well known, big Indian fruit or fox bat, of which Sir J. E. Tennant writes that "a favorite resort of theirs near Kandy, in Ceylon, was some india-rubber-trees, where they used to assemble in such prodigious numbers that large boughs would not infrequently give way beneath the accumulated weight of the flock;" and Pycraft speaks of another observer in Calcutta who is responsible for the statement that "they occasionally travel in vast hordes, so great as to darken the sky. Whether they are performing some preconcerted migration or bent only upon a foray to some distant feeding ground is a matter of speculation. These hordes are quite distinct from the 'long strings,' which may be seen every evening in Calcutta on their way to neighboring fruit-trees."

Of all the extraordinary bats none is more so than the tubed-nosed fruit bat. This species presents prolongations of the nostrils into a pair of lengthy tubes—a structure, the function of which science has as yet no explanation; further, it may be said that they do not occur in any other mammal outside of this group. Some of the insectivorous bats possess them, but they are very much smaller.

There are species of white bats found in Central and South America; they live, when at rest, among the silvery leaves of a species of coconaut palm, where the total absence of color in the fur of these animals serves to conceal them, as the white fur is noticed only by chance among the leaves of this tree. On the other hand, some bats are most brilliantly colored, and among them we find Welwitsch's bat of West Africa, specimens of which were observed by the naturalists who accompanied Col. Theodore Roosevelt on his expedition into that country; these bats possess a fur of intense orange and black.

Still more remarkable are the painted bats of India, the pelage of which presents all the brilliant colors of some gorgeous moth or butterfly. Again, in the Malayan fauna, we meet with the naked bat, an interesting species that is quite lacking in any furry coat, with the exception of a ruff of hair about the neck; it has a gland at the throat that secretes a most disagreeable fluid of an oily consistence, and of a most nauseating and outrageous odor. As the young of this species cannot cling to the hair of the breast of the mother—as other young of the Chiroptera do when nursing—owing to her naked skin, it has come to pass that a deep sac has developed on either side of her body which form receptacles for her young.

In an 1846 edition of Darwin's "Voyage of a Naturalist" (vol. 1) in my library, I read, on page 27, a note by that great naturalist to the effect that "The vampire bat is often the cause of much trouble, by biting the horses on their withers. The injury is generally not so much owing to the loss of blood, as to the inflammation which the presence of the saddle afterward produces. The whole circumstance has lately been doubted in England; I was therefore fortunate in being present when one (*Desmodus d'orbignyi*, nat.) was actually caught on a horse's back. We were bivouacking late one evening near Coquimbo, in Chile, when my servant, noticing that one of the horses was very restive, went to see what was the matter, and fancying he could see something, suddenly put his hand on the beast's withers, and secured the vampire. In the morning the spot where the bite had been inflicted was easily distinguished from being slightly swollen and bloody. The third day afterward we rode the horse without any ill effects." (Pp. 27 and 28.)

A short, but very excellent, account of these blood-sucking vampires is to be found in a work entitled: "Through Southern Mexico," by Dr. Hans Gadow (London, 1908, pp. 440-442), of which my library contains a gift copy from its distinguished author.

Dr. Gadow succinctly describes the extraordinary physiological and anatomical modification in the vampires studied in Mexico by him, which so thoroughly fit them for their blood-sucking propensities. Among other things he says: "The exclusive blood diet of these creatures has brought about an absolutely unique modification of the stomach. While the œsophagus is such a narrow tube that nothing but fluid blood can pass through it, the stomach is transformed into a long, left-sided, blind sac, which is several inches in length, and coiled up upon itself." Huxley also wrote upon this subject, his paper appearing in the 1865 "Proceedings" of the Zoölogical Society of London with a figure (pp. 386-390).

The bite of the vampire bat is like the bite of a big leech, for the blood fails to coagulate on the wound after the bat has left off sucking it; and there is reason to believe that one of the constituents of the saliva of this species of chiropteran has something to do with this fact.

As the Doctor points out, there were no horses in Mexico or Peru prior to the coming of the Spaniards to those countries and introducing them. Cattle are not attacked, for they can keep the bats off with their horns and long tails, when they possess the former.

What did these bats feed on, then, before horses and cattle came into the New World? Surely not on birds of any kind. Maybe on the *deer*, or perchance, on some of the other large mammals of those countries; but this can be but a speculation upon the subject. In any event, the geographical range of the vampires has been greatly extended since the time of the arrival of the horses, and may be slightly extending still.

Many of the older naturalists believed that these South American vampires preyed upon both men and cattle; Azara, for instance, stated that the inhabitants of Paraguay, although they did not fear these big, blood-sucking bats, the animals frequently entered their houses nevertheless and would suck the blood from any person they caught asleep, and were quite indifferent as to what part of the body they chose. The ill effect following the bite and bleeding was very slight, being only a mild sensation of pain for a day or so.

On the other hand, Tschudi speaks of a drunken Indian who fell asleep in the woods, and upon being bitten by a vampire, his face swelled up so that no one recognized him. Probably the alcohol had something to do with this, if the story be true.

It is said that the natives sometimes use the Roussette fruit bat, one of the largest species of the Order, as food, and esteem it very highly. A "Roussette" is a common name for several species of these bats in Java, where they are much dreaded on account of the havoc they play with the domesticated fruits. These they are often obliged to protect by the use of loose nets or by baskets of split bamboo.

During the day these animals hang in the trees in thousands, suspended head downwards; they appear as though they were in rows, as they are strung along on the smaller limbs, most of the host being perfectly quiet unless disturbed in some way. This attitude is well shown in Fig. 6.

As evening advances they take to flight, the army of them repairing with unerring certainty to the native gardens, where they devour fruits of all kinds, including melons, oranges, etc.

Whether the ancient Jews were directed by their priests not to eat bats is a question; it is a well known fact that in the Bible of the Christians, this mammal is reckoned as a bird, and doubtless was so considered by the zoölogists of that work; this being the case, it was not forbidden to Jews of those countries in Asia where bats occurred.

Some of the works on popular "natural history," which appeared during the middle of the last century, held forth very learnedly about what the "ancients" thought of these animals. For example, one writer remarks that though "the bats are, upon the whole, useful rather than hurtful to man, they are creatures to which poetry and superstition have in all ages had recourse to deepen the feelings of loathing and horror. They are not only of strange forms, but they are things of the doubtful light—the dim twilight—which in ages of ignorance converts white stones into ghosts and bushes into specters. They dwell in the ruined wall, or riven earth, or gloomy cavern: in eastern countries they often find their way into the sepulchers and catacombs of the ancients. They have been observed, therefore, as dwellers with desolation and death; and it was stretching the imagination but a little further to suppose that they were in league with those loathed and dreaded powers.

"The rapacity of the larger bats, such as are found in the warm countries, feeding during the twilight gloom, gave color to those suppositions. Hovering about the Pagan temples, they ate greedily the blood and other remains of the sacrifices. When famine or pestilence, which were then of frequent occurrence, strewed the earth with the bodies of the dead, or when night closed upon the horrors of the battlefield, the bats thronged to the nocturnal feast. As in all cases they came dim and apparently formless, with wing most unlike any organ bearing the same name which is spread to the light of day, they perfected their claim of poetical alliance with the infernal regions, and the powers which hold dominion over them. Hence, as the peacock was the bird sacred to Juno, the queen of Heaven, so the bat became the creature sacred, or accursed, as may be, to Proserpine, the Empress of Hell.

"The use of bats for these purposes is as old as Homer, who very skillfully manages them in heightening the graphic effect of the splendid passage in which he describes the shrieks and wailings of the ghosts in the regions of woe; and after Homer, all poets and painters who have ventured upon similar delineations have made use of the bats for the purposes of effect. Even to this day, painters must borrow the wings of bats for their devils, in the same way that they borrow the wings of doves for their angels; and one has only to throw a deep Rembrandt shade over a piece of canvas, and show a bat's wing partly displayed from a cave, in order to give an infernal air to it, with very little painting, a good poetical representation of the gates of hell. It is easy to see how a race which is linked with such associations should have had but a scanty measure of justice meted out to it by the half-superstitious naturalists of the Middle Ages; and a remnant of the same superstition is, no doubt, the cause of much of the horror which is still connected with some of the larger species of warm countries."

Although these lines were published more than half a century ago, there is still to be found in the world an enormous amount of ignorance and superstition in regard to bats.

*(This is the first of several articles on the subject that will appear from time to time.—*Ed. Note.*)*

Comet 1915 (*e*) Taylor

By E. E. Barnard

OBSERVATIONS with the large telescope were made of Taylor's comet, which has proved to be of short period.

Attention has already been called (*A. J. 29*, 138) to the fact that in the first part of February the comet was attended by a small companion. The original statement that it had a double nucleus is misleading, for the object was in every respect a double comet. I shall quote quite fully from my notes on these objects, for their subsequent behavior will make such notes valuable for the proper interpretation of the observations made before and after the full moon in March.

At first the smaller (the northern) component was the fainter of the two by 1½ or 2 magnitudes. Both objects were fairly well defined and were diffused toward the east into a short brush of tail. For a while the north, or smaller, component grew fainter and the south one—the main comet—developed a small bright condensation that was almost a nucleus. The north comet then began to brighten and became quite strongly condensed. At the same time the main comet became diffuse and fainter. It finally entirely disappeared, leaving only what at first had been the companion, which by this time was a strongly condensed comet. The position angle of the companion did not appreciably change; that of March 22 may be in error some 10 degrees—which is not probable—on account of the extreme faintness of the original comet.

The disappearance of the main body seems to have been permanent. I have not before seen a transformation of this kind in which the original comet disappeared while the companion was still visible. During moonlight, it was not possible to tell which object was under observation, as there was visible only one feeble condensation on the moonlit sky.

SOME OTHER MULTIPLE COMETS.

Brooks' comet, 1889 *V*, it will be remembered (*A. N.*, vol. cxxv., p. 177) had several companion comets, two of which remained with it for several months, and one of which at one time was brighter than the main comet. Both, however, finally faded out and apparently ceased entirely to exist, while the main comet was still bright. They have not been seen again, though the principal comet has returned several times.

Several other comets, Swift's of 1899 (*A. J. 20*, 60-61), Kopff's of 1906 (*A. J. 25*, 83-84), and Mellish's of 1915 (*A. J. 29*, 40), have also had secondary or companion comets, all of which, after a more or less brief existence, disappeared. Of course the best known example of this disruption of cometary matter was Biela's comet. One of the comets of 1860 was double. Even Halley's comet showed something of this kind in May of 1910. The great comet of 1882 for a time also showed this disruptive effect. It is, therefore, not an unusual thing for a comet to develop companions, or a double condition. This breaking up of a comet would doubtless go far to account for the fact that in several cases two or more comets are found to be following nearly the same path around the Sun, and also for the entire disappearance of some of the periodic comets.

In examining the ancient records of comets, there are several cases where apparently a double or triple comet was recorded without the telescope. One of these records, which we find in Chambers's "Astronomy," undoubtedly refers to a comet with two companions, the three, of course, being visible to the naked eye. This was in the year 896. The reference follows: "In this year there appeared three extraordinary stars, one larger and two smaller ones. . . . They traveled together for three days. The little ones disappeared first and then the large one."

POSITION ANGLES AND DISTANCES OF THE COMPANION COMET.

The comet, as has been stated, was found to be double on February 9. The position angle and distance of the two components were measured thereafter at every opportunity. Very little change occurred in the relative position of the two, the position angle remaining about the same, and the distance slowly increasing. The comet was receding from the Earth in all the observations.

NOTES ON THE PHYSICAL APPEARANCE OF THE COMET.

1916, January 5.—It was soft and diffused like some of the periodic comets. The central brightness was 10 seconds in diameter with no definite nucleus.

January 8.—Tenth to eleventh magnitude. Strong condensation but no definite nucleus. Its general light was very soft and widely diffused. It was larger than the field (5 minutes).

February 2.—Small, brightly condensed to probably a small nucleus. A 14th magnitude star close south preceding, a 15th magnitude star close north following.

February 9.—The comet was double, two perfectly distinct comets whose nebulosity mingled. The south one was the brighter and had a small bright nucleus; the north one less definite. We will call the main comet and the companion *A* and *B*, respectively.

February 26.—Both condensations almost stellar: about two magnitudes different in brightness. The nebulosity nearly filled the field and extended south following the comets. Both very little brighter preceding the middle. $A = 12^m$. $B = 13½^m$ or 14^m. The comet was faintly visible (as one) in the four-inch finder.

February 27.—The companion seemed fainter. It was 2½ magnitudes less than the main comet.

March 4.—*A* had lost its definite nucleus and was more diffused than *B*, which had almost a faint nucleus. They were both a little brighter in the middle. *B* was 1½ or 2 magnitudes less than *A*. Estimated magnitudes = 12 and 13½. Their nebulosity extended following.

March 8.—On this date the north comet (*B*) was slightly the brighter, and had a small speck of nucleus of 14½ magnitude, like a small, ill-defined star. The south component (*A*) had but little condensation and was much diffused. The two were very closely the same size. The nebulosity extended at right angles following the line between the two. There was a vague suggestion in the appearance of *A* of a possible breaking up again.

March 15.—Very faint in strong moonlight. Could not tell if it were double.

March 18.—Very faint in full moonlight. Could see only one comet.

March 22.—The north component (*B*) observed for position. It was the brighter and was definitely condensed north preceding its center and easy to observe. The main comet (*A*) was too faint to observe accurately for position. It was excessively difficult. The two seemed to have interchanged individualities.

March 24.—The south component (*A*) was not visible. What was left was simply the companion, the main comet having entirely disappeared. The greatest brightness was about ½ minute or ¾ minute in diameter, with possibly a faint speck of light slightly north of the center. The sky was not very transparent.

March 29.—Quite strongly condensed with perhaps a very small nucleus in the northern part. No trace of the original comet. Seeing 2, but sky poor.

April 1.—Only one comet, 13½ magnitude. A little brighter toward the middle, the nebulosity extending south following. No nucleus. It was 1 minute in diameter. Seeing good, sky good.

April 3.—Seen faintly for a moment before it was lost in clouds. Single.

April 5.—It was 13½ magnitude and ¾ minute in diameter, very gradually brighter north of the middle. Could see no trace of the original comet.

April 8.—It was single.

May 27.—The comet was 16 or 16½ magnitude. Very faint and diffused, but the observations are believed to be good.

A photograph was made on December 7, 1915, with the Bruce telescope. The comet was difficult to guide on with the five-inch guiding telescope. It was estimated to be 10th or 11th magnitude. The exposure was $2^h\ 50^m$ on a good sky and shows a faint tail about ¼ degree long.

Another photograph was made on February 21, 1916, with an exposure of $1^h\ 39^m$. The scale was too small to show the comet double. Though difficult to guide on, it could be seen fairly well when the light was cut off from the wires. The sky was not very good. No other photographs were made, as the results did not seem to pay for the time spent on it.—*Prof. E. E. Barnard, Yerkes Observatory, Williams Bay, Wis., in The Astronomical Journal.*

A characteristic fish culture station at Wytheville, Va.

Officials of the U. S. Fish Commission stocking a stream.

Promoting Our Supplies of Food Fishes

What the Government Does for the Producer and the Consumer

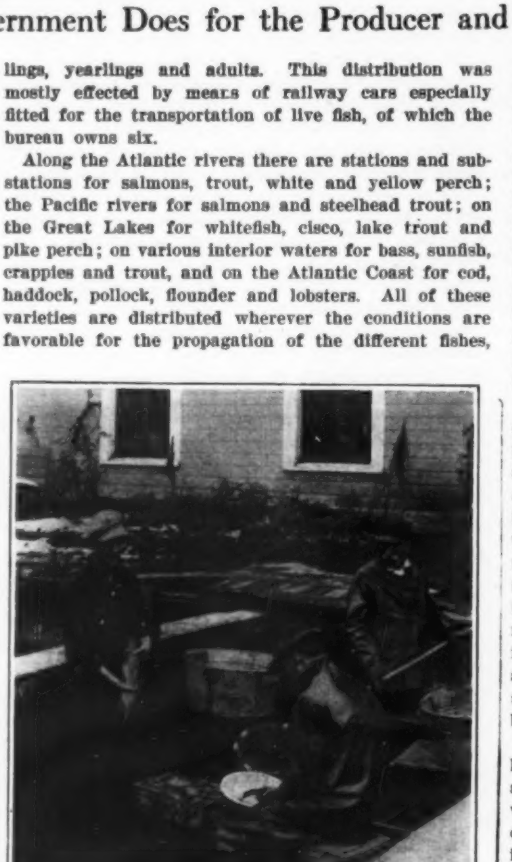
One of the several departments of our National Government that is doing work of great value to the community is the Bureau of Fisheries, of the Department of Commerce, which has charge of the supervision of propagation and distribution of food and game fishes, and scientific investigations into all matters pertaining to fish. The field of its activities is extensive, for it interests itself not only in every description of fishes to be found both in fresh and salt water, but every description of crustaceans as well, and in relation to these it investigates sources of supplies, developing new sources wherever possible, methods of propagation, capture and utilization. Its duties are by no means confined to the commercial side of the problems, for by means of frequent bulletins it tells the consuming public about new varieties of fish, or as to the edibility of well known kinds that have not been considered suitable for consumption, and also gives instructions for preparing and cooking that are of general value.

A notable example of this latter work was the introduction of the tile fish, which was practically unknown previous to the autumn of 1915. The investigators of the bureau in that year located grounds where this valuable fish was to be found, and after instructing the fishermen how to take them, a campaign of information was carried on to tell the public of this new food product, and how to utilize it. The same procedure has been followed in other cases, with advantage to the consumer.

As an example of what the bureau does for the fisherman the halibut fisheries of the Pacific Coast may be cited. For a long time the only halibut fishing grounds known were on the Alaskan Coast, which necessitated long voyages and consequent loss of time; and added to this the extension of the railway to Prince Rupert, in British Columbia, threatened the loss of the market to Seattle, as it was 500 miles nearer to the fishing grounds. In this emergency the Bureau of Fisheries undertook an investigation, with the result that excellent new fishing banks have been discovered off the coasts of Washington and Oregon, so close to the markets that the steam fishing schooners can take a full load in from two to four days; and it is believed that other equally good locations will be discovered still nearer home if the investigations are continued. While work of this kind is of inestimable value to the fishing industries it also directly benefits the consumer by affording more plentiful supplies.

Fish cultural work is another branch of the activities of the bureau, and this is being conducted in a large number of States, and in Alaska, and the greater part of the output is planted in public waters, which have included every State and territory, although fishes adapted for ponds, small lakes and minor interior waters are also stocked on individual applications. Fish cultural operations include both the gathering of the eggs of many kinds and also the propagation of fish, and during the year ending June 30th, 1915, the distribution of fish, eggs, etc., by the bureau amounted to 536,260,143 eggs, 3,694,281,699 fry and 58,215,692 fingerlings, yearlings and adults. This distribution was mostly effected by means of railway cars especially fitted for the transportation of live fish, of which the bureau owns six.

Along the Atlantic rivers there are stations and substations for salmons, trout, white and yellow perch; the Pacific rivers for salmons and steelhead trout; on the Great Lakes for whitefish, cisco, lake trout and pike perch; on various interior waters for bass, sunfish, crappies and trout, and on the Atlantic Coast for cod, haddock, pollock, flounder and lobsters. All of these varieties are distributed wherever the conditions are favorable for the propagation of the different fishes,



Collecting trout spawn at a fish hatchery.

without regard to their source, the purpose of the bureau being to promote the supplies of the entire country, and not to make the stations merely local institutions.

One interesting branch of the work of the bureau in conserving our supplies has been the rescue of young food fishes from lakes and bayous formed by the overflow of the Mississippi and Illinois rivers and their tributaries; and during the year 1915 a total of approximately 8,357,000 fish were rescued under these conditions, and returned to suitable waters, which would have been almost entirely destroyed as the overflows dried up.

Man and the Universe

"What a piece of work is man! how noble in reason! how infinite in faculty! in form and moving how express and admirable! in action how like an angel! in apprehension how like a god! the beauty of the world! the paragon of animals! And yet, what is this quintessence of dust?"

Measured by man's standards man is a mighty being, a colossus, the lord and ruler of the world, and in our younger days man seemed to be almost the lord of the universe, or at least the universe seemed to be made for him. Fortunately, as we grow older this magnification decreases until finally we see man in his true perspective—as through a telescope reversed. Then he is known to be only an infinitesimal in infinite space. He is but a speck upon a ball 8,000 miles in diameter, rotating on its axis once in 24 hours, and revolving around the Sun in about 365 days at the rate of 18.5 miles per second. Around this Sun, which is one of the smaller and cooler stars and which appears large because it is only 93,000,000 miles from us, revolve other planets—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune, in order, whose distances from it range from 36 to 2,800 million miles.

Along with this solar system of Sun, planets, meteors and comets, we speed through space at twelve miles per second, not knowing whither we go nor why. Other suns, or stars, doubtless have their planetary systems also, and all, according to our observations, are hastening through space. The unaided eye sees but 6,000 of these stars, but the telescope reveals 100,000,000. The nearest one to us is 25,000,000,000,000 (25 trillion) miles distant and heaven only knows how far is the farthest. Though light travels at a rate of 186,000 miles per second, it takes about four and a half years for light to come to us from the nearest star, α Centauri, and fifty years to come from the Pole star. Therefore some of the stars we are now seeing may have been blotted out centuries ago.

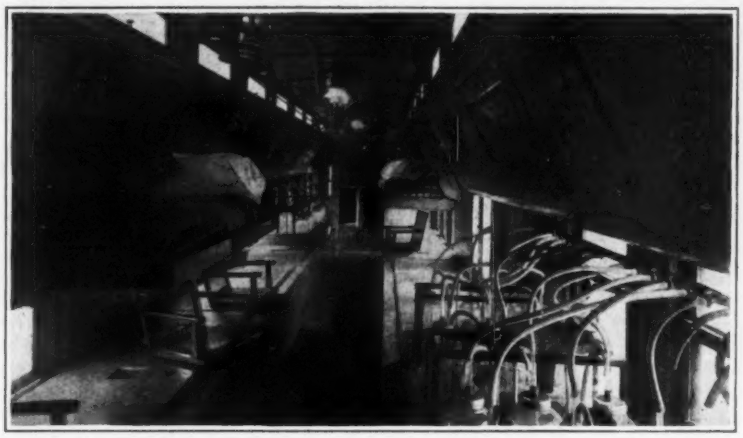
Our only visitors are meteors and comets. Several hundred meteorites have actually reached the Earth and been found. They are the remnants of former worlds that tell us that those worlds were composed of the same materials as our earth. Most of these intended visitors are burnt to powder by friction when they strike our atmosphere, and become but dust of our Earth. Some that contain occluded gas burst with explosive violence and furnish us beautiful pyrotechnics. All are small and weigh less than 500 pounds.

The comets are more distinguished visitors, but are light, airy nothings with electric tails. In passing through our solar system their orbits and motions are changed by the influence of the Sun and the planets—especially Jupiter—and thus are captured for trespassing. Many of the phenomena accompanying them are optical and electrical and change as they continue on their courses.

Of all this how much does man control? Is he monarch of all he surveys? He has no voice in their motions, no power to change the course of even one meteor. He is but an onlooker, a passenger through space without chart or compass, or even steering gear. Around and 'round he goes "on the whirligig of time circling with the seasons," which cover him with their snows, bite him with their frosts, and scorch him with summer suns; and he can not lift a hand to stay them.

Though man is but a speck compared to his habitat, the Earth itself is not so large. When we consider some measurements it seems not only large but immense. For instance, its surface contains 200,000,000 square miles, its volume is 260,000,000,000 (260 billion)

This car is employed for distributing young fishes and eggs for stocking inland streams and lakes.



Interior of Bureau of Fisheries car, showing tanks and jars for transporting young fishes and eggs.

cubic miles, and its mass is 6,600,000,000,000,000,000,000 (6,600 million million millions) tons. There are 52,000,000 square miles of land and 145,000,000 square miles of water, and living here are 1,500,000,000 persons. These numbers are large and hence our magnified idea of the size of our planet. But a square mile, a cubic mile, and a ton are all small quantities, and hence these large numbers. If it were said that a year consists of 31,536,000 seconds, one might get the idea that a year is an aeon. And so numbers sometimes fool us.

Though the earth is 25,000 miles in circumference, it can be circled in a few days. At the now moderate speed of 60 miles per hour it would require but 17 days. Its curvature shows a drop of 8 inches in 1 mile and 64 inches in 2 miles. The lower 600 feet of a mountain only 30 miles distant are below the horizon. And so it seems that our Earth is indeed a ball, and a small one at that. Its surface is nearly smooth, as its highest mountain, Everest, rises less than six miles above sea-level, and the ocean bed is about the same distance below.

Man on his island home is a creature of circumstances. If the earth's temperature were to rise 40 or 50 degrees above, or drop as much below, the present range, he would pass away and the place thereof would know him no more. Or, if the Sun's temperature were to fall as much as 14 deg. Fahr., a glacial period would occur and refrigerate us all. A slight change in the relative amounts of oxygen and nitrogen constituting our atmosphere would end our days. If the water were removed our bodies, which are 90 per cent water, would soon wither away.

Why man was placed here and whither he goes—who can tell? In spite of his insignificance and impotence, he has gazed into space and explored the starry regions. He has discovered many mysteries and solved many riddles, but the First Cause and the final consummation remain unrevealed to his intellect. And so, "there is a door to which he finds no key, there is a veil through which he can not see."

But he has seen and discovered many things. With his science he has dispelled the idea that the stars and planets are divinities, that they are candles periodically lit, and shown that they are simply masses of matter. He knows that the Earth is not flat and that it is supported neither by a tortoise nor by Atlas. Nor is the earth the center of the universe, nor even the center of one of the numberless systems. With the aid of his chemical balance and reagents he can say that the Earth's crust contains 47 per cent oxygen, 28 per cent silicon, 8 per cent aluminium, 4 per cent iron, 0.17 per cent hydrogen and 0.12 per cent carbon. With his barometer he can tell us that the atmosphere extends but seventy miles above the Earth's surface. He can point his telescope to the sister planets, see, and photograph their surface marking; with his spectrometer he can tell what elemental substances constitute the Sun and stars; and with his bolometer he can tell you that the temperature of the Sun is 12,000 deg. Fahr. and that the Moon is icy cold. With his Coulomb's balance he can weigh the Earth, and with the aid of his scientific laws determine the mass of the planets and the Moon, and predict eclipses. He has told us that the solar system was formerly a nebula, which by gravitation and cooling formed the Sun and planets. He has pointed out 10,000 nebulae, which slowly, but surely, are condensing to form other solar systems. He has discovered the cosmic process, evolution, a cyclic process without beginning and without end, progressive and continuous. From internal evidence he finds that the Earth has reached the age of some 60,000,000 years. Though still cooling and contracting its end is in the dim and distant future. Within its surface much heat is stored, for as we dig down its temperature increases 1 deg. Fahr. for every seventy feet. The Sun, a mass 880,000 miles in diameter, has cooled more slowly and its temperature is yet 12,000 deg. Fahr. Through calculations it is known that the Sun's heat is not due merely to cooling, for if it were its temperature would not long remain constant. As it cools, it contracts; as it contracts, its temperature is raised; and thus its heat is maintained. Another factor in this maintenance is the wonderful metal radium, which undoubtedly exists in the Sun. This metal is a heat factory in itself.

Not only has he delved into the past, but he has dipped into the future and predicted discoveries of other worlds. The prediction and discovery of Neptune, the farthest known planet, is evidence of his ability and acumen.

Deep sea fishermen returning to their vessel after hauling a trawl.

Fishermen hauling a seine in the Detroit River.

Man's inquiries have not been limited to the inanimate matter of the universe. For centuries he has wondered whether worlds are inhabited. It was formerly thought that all of the planets, stars, Moon and Sun were inhabited, but now we know that this cannot be unless their residents are far different from us.

In ancient times it was said that the heavenly bodies were round because the circle is the perfect figure. It was also thought that their motions and conditions were permanently fixed because established by a perfect creator. Though the motions and forces of the Sun, Earth and Moon are finely balanced, we know now that sooner or later their equilibrium will be destroyed and that the Earth will be ground to pieces by the Moon or fall into the Sun to be destroyed by fire. Whether the Earth will be refrigerated and depopulated long before such a cataclysm occurs, man cannot yet tell.

As the solar system is speeding toward the constellation Hercules, perhaps to join the cluster of 6,000 stars observable there, the avoidance of a collision with other systems seems impossible. Such a collision would start another cycle in the evolutionary process. Thus one cycle follows another, but all are in the same progressive march through eternity. Was there a beginning? Man can find no evidence of it; nor can he find any promise of an end. The present stage is but a phase of the endless cosmic cycle: condensation—collision—heating—nebulae; then condensation, collision, etc., again. The Creator has not finished his work—and never will. "He is ever present, ever working throughout the universe—an Infinite and Eternal Energy." And

"When you and I behind the veil are past,
Oh, but the long, long while the world shall last,
Which of our coming and departure heeds
As the sea's self should heed a pebble cast."

Man has not only made measurements and calculations of things seen, but has also launched his mind upon the sea of infinity to explore its unknown shores and answer the riddles that he meets. He does not balk at the question, "Is the universe infinite?" though he knows that he can not conceive of infinite space because the idea is beyond the power of his imagination. But this fact does not prevent an answer to the question. As Spencer has said, "Conceivability or non-conceivability is never proof." Man employs his reason and argues that since everything occupies space, space can be limited only by space. Therefore, it is self-limited only, and therefore endless and infinite. Again, who would deny that 1.0/3 gives an endless result, an infinity of 3's? Yet imagination can not cope with them. Thus reason attests an infinity though imagination can not reach it. Again, reason suggests that time is infinite—without beginning and without end—but mind can not grasp the idea.

So man, the quintessence of dust, is but a mote in an infinity of infinities. Though his "dim horizon is bounded by a span," he gazes intently at the passing show that comes within his ken—an onlooker who can control nothing—one of the "magic shadow shapes that come and go 'round with the sun-illumined lantern held in midnight by the master of the show; one of the helpless pieces of the game He plays upon this checker-board of nights and days, hither and thither moves, and checks and slays, and one by one back in the closet lays."

Through infinite space he whirls in complex spiral motion at thirty miles per second, speeding on and on until his days are ended. Like the poor player upon the stage he struts and frets until his part is done. He is but a "flower of the field which to-day is and to-morrow is no more." "He dieth and wasteth away: yea, man giveth up the ghost, and where is he?—*C. M. Kilby in Popular Astronomy.*

Conversion of Coal Into Soluble Substances by Means of Ozone

By treatment with ozone the chief constituent of coal, corresponding to the original cellulose, is gradually converted into soluble products. For example, by six successive ozonizations of fourteen to forty hours, 92 per cent of a sample of coal was rendered soluble in water. The soluble substance was dark brown, and had an odor of caramel and a pronounced acid taste. It was slightly soluble in alcohol, very sparingly soluble in ether, and nearly insoluble in petroleum spirit. It dissolved in ammonia, alkali solutions, and acids, and formed precipitates with the acetates of heavy and alkaline-earth metals.—*F. Fischer, Ber. From note in Journal of Society of Chemical Industry.*

Capillary and Electrocapillary Chemistry—I*

A Survey of the More Important Phenomena, and Technical Applications

By W. C. McC. Lewis, M.A., D.Sc., University of Liverpool

CAPILLARY chemistry, as the name suggests, deals with phenomena which occur at the surface or interface which separates two phases. The term "surface" or "interface" in this connection does not refer to the mathematical concept of a surface (which has no physical existence). What is meant is the very thin interfacial layer caused by the interpenetration of both phases, which extends to a very slight depth not exceeding the effective range of molecular attractions, that is in all probability a few millionths of a centimeter. It might be thought that effects which are limited to such dimensions would never play any significant *rôle* in physico-chemical phenomena. This is true up to a certain point. Given the proper conditions, however, surface effects play not only a significant, but even a decisive part in the observed phenomena. The necessary condition is that the surface shall be large compared to the mass or bulk of at least one of the phases. Under this condition it is to be expected that the force known as surface tension may lead to the production of phenomena not observable when the phases which constitute the system are present in bulk. To illustrate the point, let us consider the phenomenon of absorption. Suppose we have an aqueous solution of say sugar in contact with an oil in which both sugar and water are insoluble, then if the presence of the sugar modifies the interfacial tension between the oil and the water, it will be found that the concentration of the sugar in the interfacial layer is not identical with its concentration in the bulk of the solution. This surface-concentration effect is denoted by the term adsorption, to distinguish it from absorption which means the distribution of the solute throughout the entire bulk of a phase. The phenomenon of adsorption is one of the most important and characteristic features of capillary chemistry. It was first put on a sound theoretical basis by Willard Gibbs, who showed that the phenomenon depended upon the effect produced by the dissolved substance upon the value of the interfacial tension existing between the two immiscible phases. Gibbs proved by thermodynamic means that if a dissolved substance was capable of lowering the interfacial tension, then the substance would be positively adsorbed at the interface, that is, its concentration in the surface layer would be greater than its average concentration in the bulk of the same phase. On the other hand, if the dissolved substance was capable of raising the interfacial tension it would suffer desorption at the surface, that is, its surface-concentration would be less than its average concentration in the bulk of the phase.

One can test Gibbs' expression by forming an emulsion of, say, hydrocarbon oil in an aqueous solution of some substance which is quite insoluble in the oil in the ordinary sense, but which has the property of lowering the interfacial tension oil-water. It will be found that the concentration of the dissolved substance throughout the bulk of the water is less than its concentration previous to the formation of the large interface produced by emulsifying the oil. That is, some of the substance is now closely adhering to the oil-water interface at a higher concentration than that possessed by it in the bulk of the water. The bulk concentration has consequently been depleted to allow of the adsorption layer being formed. Two conditions are postulated in Gibbs' deduction, first, the phenomenon must be reversible, that is, if the concentration of the solute in the bulk of the aqueous phase be diminished the surface concentration must likewise diminish, and secondly the bulk concentration must not exceed the limits of applicability of the perfect gas laws.

The reference to the term *emulsions* suggests two other kinds of systems very similar in nature and behavior, namely *suspensions* and *colloidal solutions*. Suspensions, emulsions, and colloidal solutions are all ultimately governed by the same laws. They are all fine grained systems, possessing large interfacial area compared to the mass of the disperse phase. Suspensions represent systems having the largest size of particles (diameter approx. 10^{-4} centimeters), emulsions come next with diameter of the order 10^{-5} centimeters, and colloidal solutions represent the highest stage of subdivision with particles the diameter of which is usually of the order 10^{-6} centimeters. It is an important though not easily understood fact, that great variation in size of the particles in one and the same system renders the system an unstable one, with the result that the particles, instead of remaining in permanent distribution throughout the liquid medium, agglomerate or coagulate, giving rise to a jelly-like mass, called a *gel*, to distinguish it from the stable suspended state, which is termed the *sol*. Since suspensions, emulsions, and colloidal solutions are characterized by the possession of large interfacial area, it is obvious that adsorption effects may take place upon the particles of these systems, just as in the case of porous bodies possessing large surface area, such as charcoal, textile fabrics, paper, sand, and soil. Suspensions, emulsions and colloidal solutions possess in addition certain well-marked characteristics more particularly associated with the phenomenon of their stability in the disperse or sol form, and the conditions which determine the conversion of the sol into the agglomerated or gel form. It is necessary to consider some of these characteristics very briefly and, for the sake of simplicity, we shall restrict ourselves to colloidal solutions.

The first point is the determination of the average *size of particles* in a colloidal solution, or what amounts roughly to the same thing, the apparent *molecular weight* of the colloid in the sol form. From the fact that colloid particles are invisible under a high power microscope, Bredig inferred that the diameter must be less than 10^{-4} centimeters. From the fact that colloidal solutions possess the property of polarizing light, Lobry de Bruyn concluded that the diameter could not be less than 5—10$\mu\mu$, that is, of the order 10^{-6} to 10^{-7} centimeters. Other considerations also based upon optical effects have led to the value 5×10^{-6} centimeters for the average diameter of colloidal metals. As regards molecular weight, the result of applying the ordinary osmotic expression—which, by the way, seems to be a perfectly justifiable procedure in view of the work of Perrin and others—has led to enormous values, e. g., 5,000 for gelatin, 15,000 for albumin in water.

A further point of interest is the so-called *Brownian movement*, exhibited by suspended particles and due to the bombardment of the particles by the molecules of the medium. Although this phenomenon is of great theoretical interest it is not proposed to consider it further in this place, since in the few technical applications of capillary chemistry which it is proposed to deal with later no explicit use of the phenomenon is made.

We may now pass to what is probably the most important phenomenon in connection with colloids, namely, the *electric charge* which the particles possess and the mechanism of *coagulation*, which is intimately connected with the removal of the electric charge. Practically all particles in the stable colloidal or emulsoidal state are electrically charged. In aqueous solution, colloidal metals, sulphides, and oil emulsions are negatively charged while colloidal hydroxides and many organic substances are positively charged. The sign of the charge is most conveniently determined by placing the colloidal solution or emulsion in a U-tube fitted with platinum electrodes and observing the direction of motion of the particles under the applied electromotive force. This movement is termed *cataphoresis*. When the particles arrive at the electrode, which is naturally charged in the opposite sense to that of the particles themselves, the latter are discharged and coagulate together to form a gelatinous mass at the electrode which is easily distinguishable by the eye. It is a remarkable fact that the removal of the charge should bring about coagulation. The simplest view of the matter, though probably an inadequate view, is that coagulation is prevented by the electrostatic repulsions of charges of the same sign, and that when the repulsion is removed by the discharge, the accidental impacts of the now uncharged particles result in the building up of large aggregates which are precipitated by the action of gravity. That gravity does not cause the precipitation of individual particles even apart from their charge is probably due to the fact of Brownian movement, the particles being retained in suspension in virtue of the bombardments by the molecules of the medium. A matter of the greatest uncertainty is the problem of the ultimate source of the electric charge which the particles carry. We know that colloids can be discharged and coagulated, not only by contact with an oppositely charged electrode, but also by means of electrolytic ions of opposite sign, the coagulating effect of such ions increasing generally with their valency. Thus Al··· ion, which possesses three positive charges, is a better coagulant of a negatively charged colloid such as colloidal arsenic sulphide than is Ba··, which carries two positive charges, and this in turn is much more effective than a monovalent ion such as Na·. In view of the fact that ions can bring about discharge, it has been inferred that the charge in the first place was conferred by the absorption upon the surface of the colloid of one of the ions of the medium, say H· or OH', when water is the medium. Such a view as this receives considerable support from the behavior of a colloid such as albumin, which has been shown by Hardy to be neutral or nearly so in pure water, positively charged in acid solution where H· is in excess, and negatively charged in alkaline solution where OH' is in excess. I am inclined to think, however, that albumin is rather a special case. The difficulty of accepting the ionic-charge view as a sufficient one is evident when it is remembered that colloidal solutions may be obtained in media in which it is difficult to believe that ions exist. Thus Billiter has prepared colloidal platinum in chloroform, in which the colloid is electrically charged, and what is equally remarkable the charge is a positive one, although in water, colloidal platinum is negatively charged. Further, the process of spraying liquids through an orifice into a vacuum or into a gas confers a charge upon the particles. This process is hardly distinguishable from the more familiar cases of frictional electricity. In my opinion the origin of the charge carried by a colloid or emulsion particle is the same as that which we recognize as frictional electricity.

In this connection it is very significant that in general the sign of the charge carried by a particle is determined by the relative values of the dielectric constant of the disperse phase and the medium, the phase which possesses the higher dielectric constant being the positively charged one. Now water is a substance with a characteristically high dielectric constant and it is to be anticipated therefore that in the majority of emulsions and colloidal solutions which contain water, the water will be positively charged with respect to the particles, or, what is the same thing, the particles will be negatively charged with respect to the medium. Although one can obtain positively charged colloids in water it can probably be stated that the majority of colloidal solutions in water contain particles which are negatively charged. It would be rash, however, to believe that dielectric constant is the only determining factor. Even granting the frictional idea we are still met with the difficulty of visualizing with any degree of clearness the relative distribution of the opposite charges existing respectively on the particle and upon the neighboring molecules of the medium. The usual view is due to Helmholtz and is, therefore, spoken of as the "Helmholtz double-layer" theory. According to this, a colloid particle and the surrounding layer of molecules of the medium can be regarded as a small condenser with a certain potential difference between the surface of the colloid and the nearest layer of molecules.

But this does not really take us very far unless we postulate something further about this system. It will be observed that a system represented by a charged colloid particle surrounded by a layer of oppositely charged molecules is, strictly speaking, electrically neutral as far as an external field of force is concerned. An effective charge can only be produced in such a system if there is a certain amount of "give" between the nucleus and the outer layer and the fact that colloids do move in an electric field is evidence that such a "give" takes place. Lamb (*Phil. Mag.*, 188) is practically the only investigator who has attempted to deal quantitatively with this point by introducing a factor called the "facility of slip" into his expression for the potential difference across the "double-layer." It is obvious that any attempts to determine the *actual* charge carried by a colloid particle are very liable to error. What we do measure is the much smaller quantity, namely, the *effective* charge which is dependent upon the magnitude of the facility of slip. If the facility of slip were zero, that is if there were no "give" between the layers, the colloid-condenser system would possess no effective charge at all, though the true charge upon the particle might be considerable. The results of such determinations have hitherto been very discordant and we really do not know with any

*Journal of the Society of Chemical Industry.

certainty the true charge on a colloid particle.[1] Although this is the case with regard to the charge, the value of the potential difference between the colloid particle and the surrounding medium is much more accurately known. We are particularly indebted to E. F. Burton (*Phil. Mag.*, 1906) for having carried out the first quantitative measurements in this direction. As a rough approximation one may say that the potential difference amounts to 0.05 volt for practically all colloids and emulsions. The determination of this potential has great significance for the phenomenon of coagulation, for it has been found that by addition of a suitable electrolyte it can be reduced to zero, and may even be carried through zero to real values of opposite sign. The position at which the potential difference is zero has been called by Hardy the isoelectric point, and it was considered that this corresponded to the optimum condition for coagulation, or what is the same thing, at the isoelectric point the colloid is most unstable. Although this is nearly true, the actual coincidence of isoelectric point and maximum instability has been called in question. This problem is therefore in a state of considerable uncertainty. A similarly unsatisfactory state of things exists in relation to the discharging effect produced by ions when we come to examine the phenomenon closely. It is easy to conceive of a positive ion, such as Al···, being adsorbed upon a negative colloid and discharging it—but what *rôle* are we to attribute to the negative ion originally associated with the Al··· ion? It is known, for example, that aluminium sulphate possesses a different coagulating power from aluminium chloride—but why? We can only say that we do not know. Even the recent work of Bancroft (*Trans. Amer. Electro-Chem. Soc.*, 1915, 27, 175), which has increased our knowledge of such phenomena very considerably, does not get us further than the conclusion that there is a *specific* adsorption effect entering in all cases, specific not only with respect to the ions, but likewise with respect to the colloid. It is clear that an immense field lies untouched in such problems as these.

Before passing from the problem of electric charge and coagulation it is necessary to deal very briefly with the closely allied phenomena of *colloid-protective effect* and *peptonization*. It is well known that a colloidal solution of platinum in water can be rendered much more stable by the addition of a small amount of gelatin. The gelatin acts as a preservative. In this case one colloid stabilizes or protects the other. In the phenomenon of peptonization we have what may be described as the reverse of coagulation. That is certain gels may be converted into sols by the action of reagents. Thus the gel hydroxides of zinc, aluminium, and chromium can be converted into the sol form by addition of excess of caustic potash. It is to Bancroft (*loc. cit.*) that we owe the idea that protective effect and peptonization are one and the same thing. To illustrate the point a sentence or two may be quoted from a recent paper by Bancroft (*l.c.*) dealing with the behavior of mixtures of chromic and ferric salts with excess of alkali. "Hydrous (hydrated) chromic oxide is peptonized by caustic potash while hydrous ferric oxide is not. If the chromium salt is present in large amount relatively to the iron salt, the ferric hydroxide will adsorb the peptonized chromic hydroxide and be peptonized by it, thereby going apparently into solution. If the ferric salt is present in excess, it will adsorb the peptonized chromic hydroxide, carrying it out of the liquid phase. It is to be noticed that the chromic hydroxide, when in excess, acts as a so-called protective colloid to the iron hydroxide."

There still remains one other phenomenon of capillary chemistry the importance of which is very great both from the scientific and technical standpoint, namely, the phenomenon of *electro-osmosis* or *endosmosis*. By electro-osmosis is meant the movement of a liquid through a membrane or through a capillary tube toward one of the electrodes when the membrane or tube is placed in an electric field of force acting between the two electrodes. The phenomenon is due to the fact that at the glass-liquid interface there is a potential difference due to charges of opposite sign resident upon the glass and the neighboring molecules of the liquid. These charges are not rigidly fixed and can therefore slip from one molecule to another in a sense parallel to the axis of the tube. It has long been known that if water be placed in a vessel divided in half by a vertical porous membrane and an electrode be placed in each half, then the water will move through the membrane under the influence of the external E.M.F. so that the level rises in one half and falls in the other. This phenomenon is similar to cataphoresis with this difference, that in cataphoresis the liquid medium remains approximately stationary during the passage of the suspended particles through it, while in electro-osmosis the medium itself moves, the diaphragm being fixed. From what has been said already regarding the origin and magnitude of the electric charge on colloid particles it is obvious that our knowledge of the phenomenon of electro-osmosis is somewhat unsatisfactory. In this as in other applications of capillary and electro-capillary chemistry, technical practice is considerably ahead of theory.

[1] For a fuller discussion of the problem see the chapter on colloids contained in the Author's "System of Physical Chemistry," in Sir William Ramsay's series of Text books.

SOME APPLICATIONS OF CAPILLARY AND ELECTRO-CAPILLARY CHEMISTRY TO CHEMICAL INDUSTRY.

The following list, which is by no means exhaustive, will serve to illustrate the variety of technical processes in which capillary effects play an important *rôle*.

Rubber preparation. Vulcanization.
Separation of ore constituents.
Sprayers for crops. Soil fertility.
Rôle of colloidal iron in plant growth.
Medicinal emulsions. Milk. Cream formation.
Beverages. Liquid foods. Enzymes. Inorganic ferments.
Peptonization. Clotting. Physiological fluids.
Emulsions for photographic purposes.
Gums and adhesive materials.
Inks and marking fluids. Pigments.
Dyes and dyeing. Bleaching, tanning, staining.
Paper sizing and coloring. Carbon and other copying papers.
Soap manufacture and cleansing action.
De-emulsification of water in steam turbines.
Filtration processes. Peat drying, etc.
Sewage treatment. River sludge. Charcoal purifiers.
Colloidal metals in fused melts. Ruby glass. Opaque glass. Enamel.
Cement. Mortar. Plaster.
Rôle of colloids in electrolysis.
Contact catalytic processes.

A few of the problems involved in some of the above applications of capillarity will be considered under the following heads:

(*a*) General capillary principles.
(*b*) Technically important emulsions and colloidal solutions.
(*c*) Adsorption.
(*d*) Coagulation.
(*e*) Selective adsorption (of ions).
(*f*) Protective effect.
(*g*) Electro-osmosis.

(A) APPLICATION OF GENERAL CAPILLARY PRINCIPLES TO CERTAIN TECHNICAL PROBLEMS.

As an example we may consider the theory of wetting and the *determination of wetting power*. This is of great importance especially in agricultural practice since it is a determining factor in the efficiency of liquid sprayers. A special case has recently been examined by Cooper and Nuttall (*J. Agric. Science*, 1915, 7, 219 to 230). These investigators point out that the efficiency of a spraying liquid is not solely dependent upon the amount of toxic substance present, the wetting power being of equal importance. The wetting power depends upon the value of the interfacial tension between two phases, this value determining whether a liquid A will wet or run over the surface of a second liquid or solid B. The value of the interfacial tension can be modified by adsorption phenomena since positive adsorption necessarily accompanies a decrease in tension. The lower the tension the greater the wetting power. To get efficient spraying it is therefore necessary to have present some substance which markedly lowers the tension. For this purpose soap or a substance having a "soap basis" is particularly suitable and is therefore recommended by these authors.

(B) TECHNICALLY IMPORTANT EMULSIONS AND COLLOIDAL SOLUTIONS.

One of the most important emulsions we have already referred to in sprayers or spraying liquids. These usually consist of an oil of some kind emulsified with water which contains a substance possessing toxic properties, such as basic copper salts in the case of potato spraying to prevent potato blight. In such cases as these the emulsion which is formed by mechanical means is very far from being uniform and can scarcely be regarded as stable. In the case of medicinal emulsions, such as cod liver oil emulsion, the preparation is carried out with greater care, a much more uniform and therefore more permanent emulsion resulting. Artificial beverages are for the most part emulsions or colloidal solutions. Cocoa and coffee, for example, may be regarded as emulsions, tea as a colloidal solution. The production of tannin-free tea depends upon the fact that the colloidal tannin can be coagulated and separated. As regards natural emulsions, the most important of all is, of course, milk. Milk is only a moderately stable emulsion and in many respects this is a decided advantage, otherwise cream might have remained an unknown commodity.

Another exceedingly important emulsion which occurs naturally is rubber latex. Reference will be made to this later in dealing with its coagulation.

Besides colloidal solutions in which the liquid medium is usually water or aqueous solutions, there are a number of others which are only liquid in the sense of being mobile at relatively high temperatures. I refer to glasses and enamels. Ruby glass, for example, is a very beautiful illustration of a true colloidal solution of extremely high viscosity, the colloid being a metal, the medium a mixture of fused salts. Many such colloidal solutions have been known for centuries. Among recent preparations of such solutions may be mentioned that of translucent glass. Such substances, however, are of very complex composition, so that while one feels justified in instancing them as examples of the colloidal state it must at the same time be confessed that the knowledge we possess of colloids is far too limited to be of much use in dealing with complex cases and still less with suggesting improvements on rational lines. It would appear that empirical methods must unfortunately be relied on for perhaps a long time yet in such cases, for the lag between theory and practice is unfortunately great.

The question of photographic emulsions will be briefly considered in dealing with electro-osmotic processes.

(*To be concluded.*)

Scratching for Tin in Queensland

AMONG the inhabitants of North Queensland there is a not inconsiderable section who are inclined to work lines of their own in the bush, in country districts. One of these occupations is scratching for tin in the river courses and gutters. The object of these seekers is to collect "wash-dirt," that is tin-bearing gravel and coarse sand deposited by the water rushing down these gullies after a drought. No spot, however apparently inaccessible, is left untouched, if there is likelihood of "dirt." In rainy times—which means business—the tin-scratching industry in the hills along the watershed of Northern Queensland is in full swing, and with plenteous water for washing the scratchers use the "cradle" as their principal agent in recovering the tin which has been torn away from the hill sides by the heavy rain. A resourceful scratcher constructs his cradle out of a hollow log, which he splits in two, so that a trough of some six to eight feet long results; one end is closed by nailing a board or piece of metal across it. To this end a perforated sheet of iron is fixed horizontally, about four inches from the "lip" of the trough. This forms the catchment for the wash-dirt, and bottoms are fixed along the trough, dividing it into sections twenty inches long; these are called "ripples," and arrest the tin falling through the perforated sheet. The completed cradle is tilted lengthways, to allow the water to run away. The scratcher places wash-dirt with a shovel on the perforated sheet, or "box," as it is called, the cradle is then gently rocked and water constantly applied by a fountain with a long handle to it. With one hand the scratcher rocks the cradle, with the other he pours water into the cradle for hours at a stretch, all this, of course, so as to agitate the wash-dirt and separate the tin from the dirt. At intervals the dirt is thrown away, and the tin collected in lumps and bagged. A more ambitious way of collecting tin is by means of "sluice-boxes," that is, primitive troughs with sheets of iron nailed to the bottom. These boxes are placed in such a position in the course of a mountain gully as to receive the flow of water from artificial dams. As the water flows over the iron sheets, men standing by continuously shovel wash-dirt on to the upper end of the box, so that the tin may be deposited and the water escape. In dry times, when no water is available, recourse is had to the "dry blower" process. Bellows work over the wash-dirt, driving the light dirt from the tin. The "dirt" is placed on graduated screens, the larger mesh ones above the smaller. The dirt falls from screen to screen, the bellows being continuously employed. The tin stays on the screens, the useless dirt being blown away.—*Engineering.*

Asbestos Discovered in Arizona

LARGE deposits of long-fiber asbestos have been discovered in Arizona, in the Sierra Anchas, and are expected to relieve, somewhat, the asbestos situation. At present, about 85 per cent of the asbestos that has fibers long enough for weaving into brake lining and similar material comes from Canada, and the supply has been materially lessened since the war.

Study of Wave Motion

With a View to Counteracting the Rolling of Ships

METHODS of counteracting the rolling of ships are important from two points of view, first, that of the comfort of passengers on transoceanic voyages, and second, that of the accuracy of artillery on board battleships. Hence this question has been studied for a number of years by various engineers, notably by Bertin, former chief of Maritime Engineering in France, and by Froude in England. A *résumé* of the work done in this line is given in a recent number of *La Nature*, together with a description of the new apparatus devised by Col. Rosso, for which superiority to previous devices is claimed.

Such instruments as the alidade of Maupeou, the photographic registering apparatus of Huet, and the double oscillograph of Bertin have aided in the establishment of important laws relative to the rolling of ships, but they have permitted the study of nautical questions only upon the ship itself, and more or less completely, according to the actual conditions encountered upon the water. They have fallen short, therefore, of that theoretical perfection attained in the study of the resistance of ships' forms, which has been achieved by the observation of small models in testing basins.

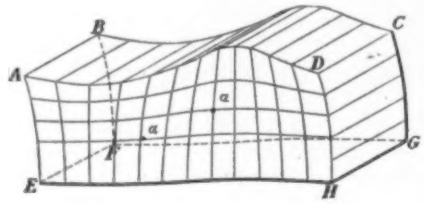


Fig. 1.

Col. Rosso, an officer of the Italian Maritime Engineers, has recently constructed an apparatus which he calls the navipendule, which accomplishes the ends desired, at least in part. *La Nature* says:

This very ingenious instrument permits the making of tests which are both very interesting and very useful from the nautical point of view, though it cannot be considered ideal. What is needed is the power to study the effect of rolling in a testing basin such as that employed for the study of the forms of boats to decide such questions as the best shape and most desirable dimensions and the proper pitch for the thread of a screw.

But for such purposes as these the surface of the water in the testing tank remains horizontal, while to study the rolling of a boat and the divers means of reducing such rolling, it is absolutely necessary that the mass of water contained in the tank shall take an undulatory movement like that of a wave in the open sea, and, moreover, the observer shall be able to vary the period, the amplitude and the height of this artificial wave in order to study the divers circumstances which may present themselves in actuality.

Up to the present time, however, experimenters have found a stumbling block in the fact that any artificial undulation produced at one extremity of the testing tank has, on striking the opposite wall of the basin, produced a shock, giving rise to return waves whose interference has seriously modified the initial undulation.

Divers testing tanks have been constructed for the artificial production of waves. In 1889 Col. Rosso employed paddle-wheels for this purpose at Spezzia. At Dumbarton the Denny Shipbuilding Company essayed to produce artificial waves in its testing tank by means of a plank immersed in the water and set in motion by hand. These efforts were without satisfactory result for the reason indicated above. Quite recently Admiral D. W. Taylor has announced the installation in the testing tank at Washington of an apparatus permitting the artificial production of waves and his hope of obtaining satisfactory results therewith. But nothing is as yet divulged as to the device employed.

Col. Rosso, the inventor of the navipendule, has quite recently devised a testing tank of peculiar construction which he submitted last April to the Institution of Naval Architects, and which, he believes, completely fulfills the required conditions for obtaining artificial waves of perfectly regular form and for unlimited variation of the conditions at sea, thus permitting the examination of the consequences of a metacentric modification or a change of form of the boat, as well as of the most efficacious means for reducing rolling and obtaining a rapid deadening of the oscillations. The device likewise allows of a comparison between the various systems of deadening heretofore employed, such as rolling tanks, gyroscopes (see *La Nature*, 1919, I, 98 and No. 2231) and equilibrium chambers with liquid ballast. . . .

The apparatus in question is based on the theory of waves propounded by *La Nature* in a previous article (1906, II, 178). According to this theory waves of the sea which have the trochoidal form when they have taken their regular form advance in a direction perpendicular to the crest and to the hollow of this wave; but this translation, as was shown in the previous article, is merely apparent and results from the displacement of the molecules of the mass of water upon the orbits which they describe to produce the wave. All the molecules found upon the horizontal plane forming the surface of the water, as well as all those placed in the horizontal planes below this surface, traverse, with equal angular speeds, circular orbits of which the diameter, which, at the surface, is equal to the height of the wave, gradually diminishes in the same degree as the depth increases until it reaches zero at a variable depth dependent upon the amount of agitation of the sea. As for the duration of the rotation of these molecules of water upon their orbit, it is always equal to the period of the wave itself, varying with the length of the latter.

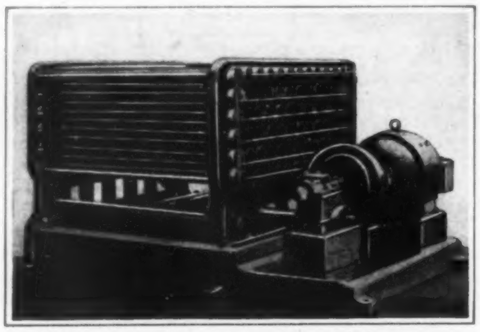


Fig. 3.—View of the apparatus, with its motor.

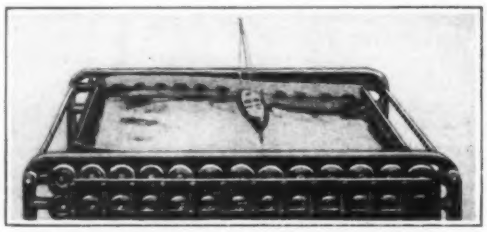


Fig. 4.—Instantaneous photograph, showing the apparatus in operation with a model on the waves.

We have given, therefore (Fig. 1), a mass of water having the plane *A B C D* as its surface and limited laterally by the imaginary planes *A D H E*, *B C G F*, *A B F E*, and *D C G H*, and at the base by the equally imaginary plane *E F G H*. Let us divide this mass of water by horizontal planes (four in this case) and by vertical planes (ten in this case). We thus form in this mass of water a certain number of rectangular prisms, in this case sixty in number. Let us suppose a regular wave to be propagated in this mass of water such as is produced in the sea, having the form of a trochoid. The surface of the water *A B C D* will then take the trochoidal form, as will likewise the four horizontal surfaces below the surface of the water. As for the vertical planes they will change position as shown in Fig. 1. In the hollow of the wave they will diverge from each other, starting from the base, and at the crest of this same wave, on the contrary, they will approach each other, starting from the same base.

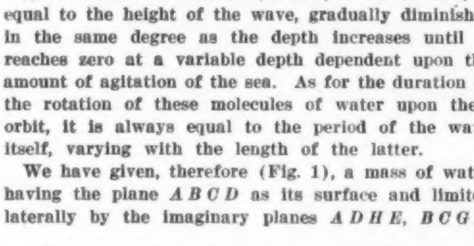


Fig. 5.—Instantaneous photograph, showing apparatus in operation, with the model at a different wave period.

Between the hollow of the wave and its crest the different vertical planes will take the direction indicated on the figure. It will be the same with the extreme imaginary surfaces *A B E F* and *D C G H*. These same horizontal and vertical planes will be modified with the advancement of the wave as shown in Fig. 2, which represents the new position of these planes after a period equal to half the period of the wave, i. e., at the moment when the crest of a wave arrives at the place of the hollow and *vice versa*.

It results from this that to obtain in a testing tank a wave of trochoidal form without producing a shock upon the opposite wall and therefore avoiding the return wave whose interferences would modify the form of the initial wave, it suffices to imitate what happens in nature by so arranging matters that the horizontal planes which divide the mass of water may be able to change their form with the advance of the wave and that the vertical planes and their extremes *A B F E* and *B H C G* may also be able to modify their inclination with the same advance of the wave.

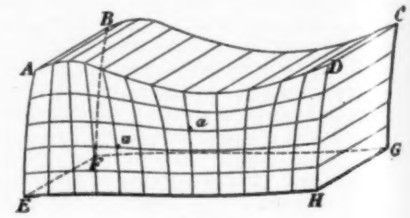


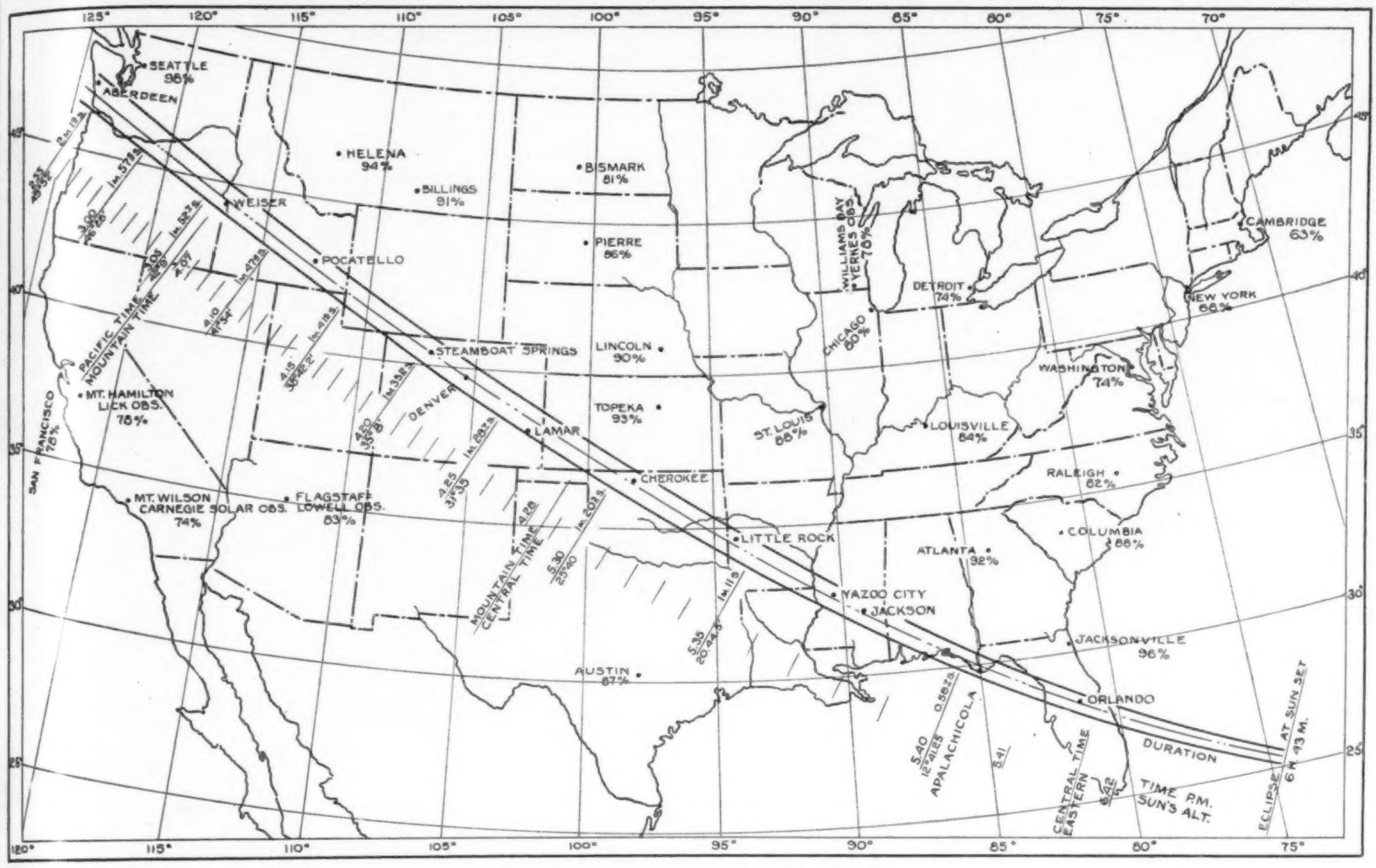
Fig. 2.

This is what Col. Rosso does in his apparatus by materializing the lateral and extreme faces which we have considered as imaginary. To this end he forms the lateral sides and the two extreme faces of the tank of plates composed of extensible substances, such as rubber, which are, therefore, capable of modifying their form and their inclination with the advance of the wave, and he unites permanently the five surfaces limiting the mass of water. In this manner the horizontal and vertical planes are capable of modifying their form and inclination according to the advance of the wave. To obtain the trochoidal form of the wave he provides at each point (*a*) where the horizontal planes cross the vertical planes, on each of the two lateral walls of the basin, a mechanism which permits him to give to the molecules of water the circular movement having the desired diameter for each of the horizontal planes, a diameter which naturally diminishes with the degree of depth below the surface. This mechanism is likewise disposed in such wise as to allow of the varying of this diameter according to the wave which it is desired to produce in the tank.

The only tank of this type which has thus far been constructed is only 1.2 meters long by 1 meter in width; the depth of the water is half a meter. In this tank waves can be produced of length varying between 0.4 meter and 3.6 meters, and of a possible height of 90 millimeters. The tank was above all, says Col. Rosso, constructed with a view to demonstration, but there is nothing to prevent larger ones being built, and according to him, a tank 8 to 10 meters wide and 15 to 20 meters long would permit the same models which serve for the study of resistance of ship forms to be employed for experiments with reference to rolling. Fig. 3 represents this tank, showing the seventy-eight mechanisms, spaced horizontally and vertically at distances of 0.1 meter, which, as we have indicated, produce the trochoidal undulations of the wave. The different mechanisms are united and set in motion by a motor which is seen in the figure, but concerning which Col. Rosso does not go into detail any more than he does as to the mechanism giving the orbital motion to the molecules of water.

Figs. 4 and 5 are reproductions of instantaneous photographs taken of a wave 1.8 meters long and 60 millimeters high produced in the tank.

According to the inventor this testing tank has given very satisfactory results, and there is reason to believe that the same good results would be obtained with the larger ones whose construction is projected.



Total eclipse of the Sun on June 8th, 1918.

Diagram showing the path of the Moon's shadow across the United States, with the Standard Times of beginning of totality, the duration of totality and altitude of the Sun. From a chart prepared at the Washburn Observatory, Topeka, Kans. (The per cent of total eclipse as seen at a number of cities is given on the drawing.)

The Total Solar Eclipse of June 8, 1918*

By Edison Pettit, Washburn College Observatory, Topeka,

On account of the favorable circumstances of the event, the total solar eclipse of June 8, 1918, will be more widely observed in this country than any heretofore. The total path length is greater than that of any eclipse seen in the United States since the eclipse of 1865, and covers more available territory than either that eclipse or the eclipses of 1878 or 1900.

It is interesting to note in this connection that this is a return of the eclipse of May 28, 1900. The length of the Saros, as determined by the ancient Chaldeans, was 18 years 11⅓ days (10⅓ days if five leap years had intervened). Now the eclipse of May 28, 1900, occurred about 8 a. m. If 18 years 11⅓ days be added to this it is easily seen how it may be expected to return at 4 p. m. on the 8th of June, 1918. As a matter of fact, a strict calculation will throw this in doubt only a matter of some minutes. The duration of totality in this eclipse is about the same as that of 1900, viz., a minute and a half. In the map the heavy underlined figures give the duration of totality as seen on the central line of the track in minutes and seconds, the light underlined figures are the standard times of the beginning of the total phase for the corresponding points in the central path. Under the latter will be found the Sun's altitude. The per cent of totality is given for various cities not on the eclipse track. To find the per cent of the eclipse for any place not on the map, deduct 1 per cent for every thirty miles the place is from the middle line of the eclipse track. Thus Lincoln, Neb., is 300 miles from the middle of the track, hence the per cent of totality is 90.

The eclipse begins when the Moon's shadow strikes the Earth on the little island of Borodino, off the coast of Japan, at sunrise, June 9, 1918. It will then sweep eastward and after the lapse of 2 hours 15 minutes will arrive at the mouth of the Columbia River, in Washington State, June 8, at 2:55 p. m., Pacific time. It is then going at a speed of thirty-three miles a minute. It then strikes southeast, will pass the Mississippi River at 5:37, Central time, and leave the coast of Florida at 6:42, Eastern time. Three minutes later it will be lost in the sunset 400 miles at sea. It will require only forty-seven minutes to travel the entire diagonal distance from coast to coast.

The long path traversed in the United States, over well settled country, makes the following scheme of co-operation seem to be not out of the bounds of possibility. Suppose an eclipse party be stationed in Washington State and another in Mississippi. Now it will be half an hour after the Washington State party sees the eclipse before it will be seen by the party in Mississippi, on account of the time it takes for the shadow to travel the enormous distance, notwithstanding its speed. Now suppose the Washington party discover what they believe to be an inter-mercurial planet. They can telegraph ahead either by cable or the wireless to the party in Mississippi and give them the details of the discovery. Thus when the eclipse reaches the Mississippi party they will be armed with the information necessary to verify the discovery. A distribution of three or four parties thus along the eclipse path will enhance the co-operative scheme.

The map shows some eighty-five towns on the direct route of the eclipse, all of which are available to travelers by rail. The original map is blue-printed on paper, 24 by 30 inches, and is being printed in blue line for us by the Santa Fé Railroad, and may be had by observatories and amateurs on application to this observatory.

*Popular Astronomy.

On the Capture of Comets by Planets

By Henry Norris Russell

It is often stated that the comets of about seventy years' period have been "Captured by Neptune," just as those of about six years' period have been by Jupiter. But, if the present ellipticity of their orbits were due to the effects of a close approach to the planet, their orbits should still pass close to the planet's orbit (unless the date of capture were so remote that the orbits had been greatly modified by perturbations in the interval).

It is well known that this criterion is satisfied by the comets of period less than ten years. The orbits of seventeen out of thirty-six of these pass within 0.15 astronomical units of Jupiter's orbit, and all the others except Encke's comet within 0.65 units. But none of the six comets with periods between sixty and eighty years comes nearer to Neptune's orbit than 3.8 astronomical units, while all six come much closer than this to the orbits of Jupiter and Saturn. There is therefore no evidence at all that these comets have been captured by Neptune.

Extending the study to the thirty-one comets with computed periods between ten and one thousand years, it is found that the orbits of seven of them pass within 0.5 astronomical units of Jupiter's orbit, of five within the same distance from that of Saturn, and of two within this distance from Uranus. The closest approach to Neptune is 1.22 units and eighteen of the comets pass nearer than this to Jupiter.

It might be supposed that the comets which pass near the orbits of the various planets had been captured by them; but, if the comets' orbits were distributed quite at random, the number out of the group of thirty-one which might be expected, by pure chance, to pass within 0.5 units of the planets' orbits is 6 for Jupiter, 3 for Saturn, 1.5 for Uranus, and 1 for Neptune. There is therefore very little left to be explained otherwise than by chance.

It appears therefore that very few of the comets with periods between 10 and 1,000 years can have been captured by encounters with any of the major planets, unless these encounters were so remote that subsequent perturbations have destroyed the evidence of capture.

This is rather surprising, for the researches of H. A. Newton indicate that, for every comet captured by a planet at so close an encounter that its period was reduced to less than that of the planet, there should be many more captured at less close encounters, whose periods after capture were longer.

We might therefore expect to find a considerable number of comets of longer period showing evidence of capture by Jupiter, and their apparent absence demands explanation.—*Popular Astronomy.*

New German Submarines Without Periscopes

The Italian *Rivista Marittima* states that according to news received from Holland the Germans have built submarines having no periscope. There is a lens on each side of the boat, which, combined with mirrors and other lenses properly arranged, make it possible to carry out the necessary observations. It is admitted that this improvement carries with it the disadvantage of requiring the boat to navigate closer to the surface than is the case with boats provided with a periscope, but this disadvantage is more than compensated for so it is said, by the absence of a periscope tube extending above the water surface. A powerful beam of light can be projected at night through the lens opening.

Vibrations, Waves and Resonance—IV*

The General Principles Underlying Wave Motions

By J. Erskine-Murray, D.Sc., F.R.S.E., M.I.E.E.

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2144, page 80, February 3, 1917

THERE is an interesting and fundamental phenomenon of wave motion on which I have not yet touched—it is called diffraction. When a procession of sea waves enters a harbor between the ends of the breakwaters, it does not merely go forward like a column of soldiers marching forward in parallel straight lines through a gate, but on the contrary the outer end of each wave, as it passes through the opening in the wall, curves round, clinging to the inner side of the breakwater, and thus stretching out the wave into a convex curve which sweeps over the whole surface of the harbor even into its most sheltered corners. Of course, the wave is largest in the direct line of its entrance to the harbor and becomes lower and lower as it curves round into the shelter, but there is no discontinuity, merely a tailing-off in size as the wave gets farther from the line in which it entered. The physical explanation of all this is fairly simple if one recollects that what actually takes place at any given point during the passage of a wave is merely an up-and-down vibration, and that the wave is not material in itself and has no property of inertia independent of the local vibrations which constitute it. When, therefore, a wave comes through the entrance to the harbor the vibrations spread not only forward but in all directions into the smooth waters, for each mass of water moving up and down communicates its motion to the adjacent water on all sides of it.

By a very simple experiment you can convince yourselves that a similar phenomenon takes place when light waves pass through an opening in an opaque material. Close one eye and look with the other through a narrow slit between your fingers at this candle flame. If the slit be fairly wide open you will see the candle as usual, but on pressing the fingers more closely together, and thus making a narrower slit, the flame appears to become broader and broader until it forms a horizontal band of light. Now the candle flame is itself unchanged; the apparent widening must, therefore, be due to an alteration in the direction of the rays entering the eye. The fact is that when a ray of light enters the eye from any given direction we see the source of it in that direction, whether it really is there or not. This widening, therefore, indicates that the light has spread out fanwise after passing through the slit, that in fact the waves are curving round into the shadows just as the sea waves do on entering a harbor. The same phenomenon is even more obvious with the longer electric waves such as are used in wireless telegraphy, though in this case it is usually complicated by actual conduction along the earth's surface.

Here I must point out that a conductor, in the common sense of the word, is not the only thing which will guide electrical waves; in fact, an insulator will conduct them along its surface if it has higher specific inductive capacity than the medium surrounding it. The truth appears to be that conduction is not primarily due to the fact that in a "conductor" electric current spreads by a process of diffusion in which there is energy dissipated as heat through resistance, but takes place along such a body because its dielectric rigidity is smaller than that of the air or other dielectric outside. If the body be a perfect insulator of finite specific inductive capacity, it will conduct alternate currents or waves only; but if its nature be such that it cannot permanently sustain electric stress it will also conduct a direct current, i. e., a wave of infinite length. It is this latter kind of material which is usually called a conductor; but, as you see, it has not an exclusive right to the name. As an illustration of this subject, I may say that in the conduction of electric waves in air along a water surface the large specific inductive capacity of water is actually of greater moment than the property which is usually called its conductivity. It will make this somewhat difficult subject clearer if I define conduction as the guidance of an electric disturbance by an interface between two media of different specific inductive capacity along a desired path which coincides with this interface. A simple instance will show the value of this definition. Suppose two parallel metal plates in air connected to the terminals of a source of alternating current. Now fit a straight rod of glass or other material of high specific inductive capacity from one plate to the other. The dielectric current, which was originally of practically equal density at all points between the plates, will now be much denser along the glass rod than elsewhere, and is, in fact, "conducted" by the glass rod. That this is so may be seen by twisting the rod into a curve or helix of which the ends are against the metal plates. The helix will still carry a large proportion of the total dielectric current between the plates in spite of its crookedness. It does, in fact, guide the electric current. You see, therefore, that conduction of electric waves at least is due to difference of electric rigidity, and that materials may conduct although they are perfect insulators.

In the transmission of electric waves through the atmosphere over sea and land, not only do conduction and reflection play their parts, but there is also refraction at work. Refraction is a change in the direction of a wave as it passes obliquely from one medium to another, or through a medium the density of which varies from place to place. Suppose, for instance, that a medium decreases in density as one goes upward and that the velocity of a wave of some kind is greater the rarer the medium; then if such a wave crest travels upward in a sloping direction, the end of the crest which is highest will gradually gain on the other, slewing round so that the crest forms a curve which is concave in the forward direction. The upper part of the wave will now no longer be traveling in the direction in which it set out, but will be moving in a line more nearly horizontal. It will, in fact, have been refracted in its passage through the layers of decreasing density. The same is true when the wave is traveling in the reverse direction, except that, of course, in this case the front of the wave is convex in its direction of motion since the lower end is retarded.

In the passage of an electric wave over the earth from one wireless station to another all four phenomena occur. It is conducted by the ground or sea, it is diffracted round obstacles, refracted as it passes upward or downward through the atmosphere and reflected from the upper layers of the atmosphere. Of all these actions we have now direct evidence based on a large number of careful observations in different parts of the world. In 1906 I showed by deduction from the experiments of Duddell and Taylor that the conductivity of the earth or sea over which the waves passed controlled the amount of energy transmitted to the receiving station. Some years later I deduced the existence of an upper reflecting layer from observations made by observers at the Canadian stations on the Pacific Coast. Both deductions have been amply confirmed by more recent observations, among which I must particularly mention those of Dr. C. J. de Groot, chief Government wireless engineer in the Netherlands Indies. Dr. de Groot's results are extraordinarily interesting, and show, among other things, not only a single reflection from the upper atmosphere, but even a second one, signals from a small station having been heard at distances of 3,000 and 6,000 kilometers, though quite inaudible in the intervening spaces, except, of course, within a couple of hundred kilometers of the sending station. His observations also indicate a bending of the path of the waves as they travel upward or downward through the atmosphere, and go a long way toward explaining the curious variations in the strength of signals which occur daily in all latitudes, though more markedly in the tropics.

In the few moments that remain I shall show you a couple of experiments in the shorter waves known as light. The first proves that a colored surface only shows up in its proper color if illuminated by light which contains the wave-lengths proper to that color. Here is a small lamp in which is burning spirits of wine mixed with common salt. It gives out a pure deep yellow light. Look at my face. You see it is now merely different shades of yellow, from a pale color down to a dark yellowish gray. The red pigment, therefore, does not change the rate of the yellow vibrations, but simply fails to reflect them and the surface appears dark; it, in fact, absorbs all other colors but red, which it reflects.

In this other experiment I shall show you the difference between a light in which waves of all lengths are mingled, as sound waves are, in a comprehensive noise, and one in which there are a few definite waves as when one strikes a chord on the piano. On the screen you see three parallel bands of color, the top and bottom ones showing a continuous gradation from deep red through all the colors of the rainbow to the faint heliotrope beyond the violet. These come from the upper and lower carbons of the arc lamp, and their continuity shows that the complexity of the vibrating particles in a white-hot solid is so great that all wave-lengths are given out. The middle band is the light from the arc itself, and instead of being continuous it is merely a ladder with rungs of brilliant colors, here a deep red line and there two green ones, and farther on there are others less well marked. This light comes from the free particles of hot gas between the carbons, and, as you might expect, their freedom is manifested by the radiation of definite and characteristic vibrations, no longer modified by the constraints of close aggregation as in a solid.

In my earlier lectures I have given you many instances of the generation of waves by the vibration of a fixed oscillator; I come now to the converse process, namely, the conversion of the energy of a stream of waves into the vibration of an oscillator on which they impinge. It is here that the principle of resonance becomes of such immense value, for if it were not possible to absorb and store a small increment of energy from each wave as it comes along, adding them all up until the resultant vibration of the receiver becomes of appreciable magnitude, wireless telegraphy and telephony would be extremely limited in range and utility, and such achievements as the transmission of speech from Washington to Honolulu and the Eiffel Tower would not have been possible.

Here is a simple experiment which illustrates this action mechanically. This long lath, fixed vertically in a vise, and having an adjustable weight on it, is connected to a point on a long rope stretched across the room by an India rubber band. I waggle the rope so as to cause a wave to travel forward and backward from end to end, and as each wave passes a small jerk is given to the rubber cord and thus to the lath. If the position of the weight on the lath is such that these impulses come just in time with its natural vibration it commences to vibrate, and as the impulses succeed one another the vibration becomes more and more energetic. If now I alter the height of the weight so that the rate of vibration no longer is the same as that of the incoming waves, the lath no longer gains in energy of motion but merely gives, from time to time, a few irregular movements of very small amplitude. The effect of tuning the receiver to the waves received is thus made manifest.

When we come to mechanical vibrations which are sufficiently rapid to be appreciated as sound, many striking demonstrations of resonance are possible. Have you ever thought why "intoning" is so commonly practiced in large churches, and why the clergyman who strikes the right note can make his voice carry so much further than one who does not? It is simply a question of resonance. In one case advantage is taken of the natural rate of vibration of the mass of air in the part of the building where he stands; in the other there is no resonance, and instead of the radiation of sound waves from the whole mass of air from floor to roof there are only those which come direct from the mouth of the speaker. One can get the same effect very easily in any room of which the floor is bare, and in which there is but little furniture. Sing a slowly ascending scale, passing gradually from low to high without intervals, and you will find, if the room be bare enough, that at a certain pitch the sound swells out without effort on your part, and even the faintest note uttered of this pitch seems to fill the room and lasts long after you have ceased to sing. Higher or lower notes are dead in tone by comparison and do not give the same satisfying sensation. On that note your voice was in tune with the natural vibration of the air in the room, and every vibration of your vocal chords added to the wave in the air just at the moment which helped it most.

*Cantor Lectures before the Royal Society of Arts. Republished in the *Journal* of the Society.

Other experiments we have in plenty. Here, for instance, are two tuning-forks of the same pitch or rate of vibration. I sound one with the bow, and after holding it near the other for a short time I stop it vibrating. You can hear that the other has taken up the vibration and is now going. For those of you who are further off I have arranged this large glass bead on a thread which just rests against the side of the second fork. If I repeat the experiment, you see the bead begins to jump outward from the fork and hear it clicking against it as it falls back and is thrown off again. I now put a small cap of lead on one of the prongs of the second fork, lowering its pitch a note or so as you see when I bow it. Again I try to make it resonate, but this time there is no sound and the bead no longer jumps. The forks now are out of tune.

The resonance of a column of air is well shown by holding a vibrating fork over this jar, which I gradually fill with water. As the water reaches a certain level the sound swells out and dies away again as more water is put in. There is thus a certain length of air column corresponding to each note, and the note is that which would be given out if the column of air were that of an organ pipe. These pear-shaped brass vessels in my hand have been made of such size and shape that the air in one of them resonates to this large fork, and that in the other to the small one. If I sound both forks while you put one of the resonators to your ear you notice that the sound of the corresponding fork appears to have become much louder. The amount of sound entering your ear has indeed become greater, for the resonator absorbs much more energy from the air waves than your unaided ear would do, for the simple reason that its natural rate of vibration is such that each wave arriving applies force in the direction in which the air is moving at the instant, and thus energy is absorbed in the most favorable circumstances.

There are, of course, air waves so slow that they are inaudible, and others so fast that they also cannot be heard. At one time I lived near a deep railway cutting, so deep that but little was heard of the trains as they passed. Every now and then, however, the glass door of the veranda would commence to rattle slowly, a crescendo clack, clack, clack—about four clacks per second; then it died away. On listening outside one could hear that a train had just left the station and that the puff, puff, puff was now going faster than the door could vibrate. Each puff had been a long and almost inaudible wave, and as their rate increased it had for a short time coincided with the natural vibration of the door. Sir Hiram Maxim has written a pamphlet on the bat, in which he discusses the use of the rose-like frills of skin which form so distinctive a feature of the faces of so many bats. These he suggests are organs for the detection of long air waves such as must be produced by the bat's own wings, and are therefore useful in enabling the animal to recognize the presence of trees and buildings through the waves reflected from them. The suggestion seems a reasonable one, and there is no doubt that the small vertical tongue which stands at the entrance to the bat's outer ear must have a frequency of vibration of the same order as the flapping of its wings, and should, therefore, be sensitive to the waves produced by them. Be this as it may, there is no doubt that there must be many inaudible "sounds" in the atmosphere which we could appreciate if only we had properly tuned receivers.

The use of tuned or monotone telephones, i. e., of telephone receivers which have very definite rates of vibration and therefore respond only to one note, has made it possible to send quite a large number of telegraphic messages simultaneously over the same line. At the transmitter a number of tuning-forks act as interrupters of the current, and each sends a steady stream of impulses over the line when its particular telegraphic key is pressed down. At the receiving end only that telephone sounds which is tuned to the fork used at the transmitter; and even if several messages are being sent at once on the different keys there is no confusion, for each receiver gets only the signals sent by the fork to which it is tuned. A system of this kind, invented by MM. Mercadier and Magunna, is in use in France and elsewhere, which, in addition to utility, forms a fine example of what can be done by resonance when there is perfect synchronism of the vibrator and resonator.

An interesting application of the same principle is in use by the Clyde Lighthouse Trust at Roseneath and Fort Matilda, near Greenock. The problem there was to start a light or an acetylene fog-gun by wireless control from a station a few miles away. It was solved by controlling the transmitter by means of a pendulum so that it sends out an impulse at each beat of the pendulum, while at the receiver there is a similar pendulum which gets gradually into motion as each impulse, received by the wireless set and converted into a direct magnetic pull on the pendulum, adds its quotum of energy to those which have previously arrived. Finally, when the pendulum has got a large enough swing on, it makes an electrical contact and fires the gun.

Although the energy transmitted in the two cases just described is electrical, the resonating arrangements are purely mechanical, and depend on the proper adjustment of the vibrations of masses of matter. In electrical resonance the result is obtained by proper choice of the electrical constants of the circuits concerned, and if—as is almost invariably the case—both circuits can oscillate freely, by the equalization of their natural rates of vibration.

Here is an electrical oscillating circuit. I cannot energize it for fear of disturbing the Admiralty wireless station, but I can tell you how it acts. It is, as you see, very simple—merely a piece of wire with a plate on each end. To give it more inductance, i. e., to add to its inertia, it is usually coiled up into a helix or spiral, thus. This increases the magnetic energy of the current. To add to the capacity, and therefore increase the charge and energy for a given difference of potential, the flattened ends or plates are rought near to one another so that there is only a thin wall of dielectric between them. These processes also diminish the frequency and increase the length of the wave given out, the wave length being proportional to the square root of the product of capacity into inductance. If the plates are close together there is but little radiation from the circuit; for the purpose of radiating energy, therefore, as in wireless, instead of being comparatively small plates close together they are made very large, and are as far apart as is conveniently practicable, the upper one being the aerial wires and the lower the earth itself. We can thus obtain a circuit which, though tunable to a definite frequency, will also radiate a certain proportion of the energy of each oscillation in it.

Here I may note that although it is quite properly called a circuit, no electrical oscillator is a complete *metallic circuit;* it must have in it a section where energy is stored potentially, as well as one in which the storage is kinetic. The potential or static storage takes place in the dielectric between the plates and the kinetic in the medium surrounding the conductor during the passage of the current, and these, of course, take place alternately, first one and then the other. Its frequency of oscillation can thus be adjusted by variation of either inductance or capacity, or both.

This apparatus on the table is an electric circuit containing a small electric lamp, a condenser and a variable inductance in series; it is coupled electromagnetically to the alternating current supply from a central station. You see that by varying the inductance, and therefore the natural rate of oscillation of the circuit, I can find a point at which the lamp lights up brightly, although for neighboring values of the inductance it is quite dark. The brightness, of course, indicates a large current through the lamp, and therefore shows that for this value of the capacity and inductance the circuit is in resonance with the alternating current of the supply.

In a wireless station the transmitter, as a rule, contains two circuits in resonance, the primary and the aerial, and often the low-frequency circuits are also tuned. The receiver has two tuned circuits at least, the aerial to the aerial of the transmitting station, and to one or more local circuits on the detector side. Resonance thus plays a very important part in wireless; its advantages are two in number: it enables one to work with a long train of waves of comparatively low voltage and still receive a considerable amount of energy, and at the same time insures that waves which are not of the proper frequency do not actuate the receiver unless they are overpoweringly energetic. The simultaneous working of a number of stations in the same area is thus rendered possible and the range of transmission is increased.

Photo-chemical effects, including ordinary and color photography and many other phenomena, are probably due to the resonance of molecules to light waves, a vibration being built up in the molecule which grows until the agitation is so great as to overcome attractions. The absorption of certain colors by certain pigments and colored glasses and, in fact, all coloring in nature and in art, almost certainly depend directly or indirectly upon the same principle of resonance. If time permitted I would show you some of the beautiful demonstrations which are possible, but as it is I must content myself with showing you, before we part, a couple of experiments which summarize, in a way, some of the more important points in these lectures.

Stretched tightly across the room you see this cord, and hanging from it, near each end, a pair of vibrators, each just a spiral spring with a weight attached. I start this pair in motion and you notice that one bobs up and down more rapidly than the other; the weight is smaller or the spring stiffer. At the other end the vibrators have been carefully adjusted to have the same frequencies as these. Note the effect when I start one at this end, the slow one, for instance. Almost immediately the slow one at the other end commences to move up and down and after a few swings is going strongly. The other keeps almost quite still. The vibration having ceased, I start the quick one, and immediately the corresponding one at the other end commences. Each answers only to the timed impulses sent along the cord by that which is "in tune" with it. Now I start both vibrators and both those at the other end respond. I alter the rates of vibration of either pair by adding or subtracting weights, and now, beyond a few feeble and erratic waggles, there is no response at all.

Here is the demonstration in a slightly different and even more interesting form. Over each end of this long watertrough two vibrators are suspended from firm supports. As before, they are in pairs, a rapid and a slow one at each end. The weights are partially submerged in the water, and if I move one up and down it sends out waves which you can see traveling along the trough. In a few moments you see the corresponding vibrator at the other end begin to move, and as before each is actuated only by the one of its own frequency. If both are started both respond, and if the frequency of either is altered there is no response.

Here, then, we have a vibration producing a series of waves, and, if there is a vibrator whose frequency is that of the incoming waves, an absorption of energy by resonance. We have also a proof that if the vibrator is not tuned to these waves the energy is not absorbed. Again, there is the proof that two sets of waves can co-exist in the same medium without mutual destruction, for when both vibrators at one end were started both those at the other answered to them and the only connection between them was the water, on whose surface both waves must therefore have existed simultaneously. In like manner we can see how two or more pairs of wireless stations can be worked independently and without interference in the same district; and how, as in Squier's "wired-wireless" system, a message in high-frequency currents can be signalled along a wire on which a telephone conversation is going on, without either set of waves interfering in the slightest degree with the other, indeed without the one message being even perceptible in the instrument used in receiving the other.

To the many and strange actions with which we have dealt, I must add the suggestion of another. When two particles, one positively and one negatively charged, revolve round one another they give out an electric wave whose period is that of their revolution. Thus there is reason to suppose that the waves of light, each a very small fraction of a millimeter in length, given out by a molecule of heated gas may originate in this way. Now the sun is probably positively charged while the earth is negative, and the one revolves round the other in a year; so, radiating from our system through interstellar space there are probably electric waves whose period is a year. Think of the length of them. They travel at three hundred thousand kilometers a second and each wave is a whole year long. Three hundred thousand times the seconds in a year is its length in kilometers. I leave the calculation to yourselves.

Recent German Aeroplanes

In new aeroplanes built by the Germans there is a tendency to decrease the length of the fuselage, the average length of which is now twenty-six feet, compared with thirty feet before the war. Ailerons are used on all types and of peculiar design. The interplane bracing has been much reduced in recent models. On most of the machines in use at present there are eight metallic struts, connected by a simple rectangular system of wiring, in place of the complicated cantilever truss for which German construction used to be noted. The connection from the fuselage to the upper wing is made through a pair of supports in the shape of an inverted V. These offer no more resistance than the old system of four short vertical struts, and are much stronger. The wings are now covered with a yellowish cloth, and doped with a transparent varnish of a bluish tint, which makes the wing difficult to pick out against a blue sky.—*The Engineer.*

Utilization of the Discharge Through Gases

THE study of the electric discharge through tubes filled with gases, rarefied or not, has so far been almost entirely of the nature of purely scientific research. Some recent experiments conducted by Prof. F. Skaupy, of Berlin, however, open out further hope of technical utilization. Skaupy observed that gas mixtures are separated into their constituents when the discharge passes through them, the one constituent collecting near the cathode, the other near the anode, and that it is possible to withdraw and to isolate those constituents. He further found that certain reactions and polymerizations take place in mixtures of vapors and gases exposed to the discharge, and he expresses the opinion that atmospheric nitrogen might be bound in this way by the glow discharge, instead of being oxidized by the arc discharge. His first communication, made to the Physikalische Gesellschaft (*Verhandlungen*, April, 1916, page 230) and his subsequent communication presented to the Deutsche Chemische Gesellschaft (*Berichte*, September, 1916, page 2,005) are little more than preliminary, and it will be a long step yet to technical application. But the investigations are certainly very suggestive.

Sending the continuous current discharge through a neon tube, containing 10 per cent of argon, at a pressure of 5 millimeters, Skaupy noticed that the anode spectrum showed, after a few minutes, the very characteristic neon lines, the cathode spectrum the argon lines, while the glow of the middle portion of the tube (300 millimeters long, 10 millimeters wide) gave intermediate spectra. Mixtures of helium and argon behaved similarly, and it was found that the gas possessing the lower ionization potential collected at the cathode. In mixtures of three gases, the gas characterized by the medium ionization potential was concentrated in the middle portion of the tube. By feeding new mixture into the middle portion of long tubes and by withdrawing the gas from the neighborhood of the electrodes—which were alkali metals in these experiments—Skaupy succeeded in separating and purifying the gases. The explanation suggested is that every gas has its own ionization potential, the potentials of the rare (noble or inert) gases being higher than those of the common gases. The gas with lower potential will be ionized to a higher degree than the other, and at any particular spot the proportion of the positive ions of the former gas will be greater than would correspond to the original gas mixture; the positive ions will move toward the cathode. When vapors of mercury or salts are added to the inert gases, for the purpose, for instance, of increasing the luminosity of the glow discharge, the active ions will also travel toward the cathode therefore. Such additions, Skaupy points out, have sometimes been made to gas-glow tubes without any result, probably because the vapors had not been introduced at the anode; if introduced at the cathode they would remain there and would not make the glow of the discharge column more brilliant.

The use of inert gases as diluents of the vapors had the advantage that they allow of working with relatively high current intensities, and that they do not attack the electrodes. When a vapor is added to the gas the vapor may be decomposed by the discharge and the constituents be separately condensed or absorbed. Many vapors are slightly dissociated to start with, and the discharge will increase the dissociation and preferentially separate those dissociated particles. Thus when vapor of aluminium chloride is introduced into the middle of the tube, the ions of metallic aluminium travel toward the cathode and can be condensed there by enlarging the diameter of the tube, while the chlorine is bound by the anode. But the discharge may also favor combination or polymerization by bringing the suitable constituents into contact with one another. Thus vapors of hydrocarbons led into the tube condense to colored (generally yellow) polymerization products on the cold walls of the tube; there is no carbonization, as would result with the arc discharge or with incandescent electrodes. Skaupy has also obtained condensation products from mixtures of vapors of organic substances with free nitrogen. This novel way of binding atmospheric nitrogen will probably excite foremost attention at the present time. It will be understood that the inert gas is the carrier of the electric discharge, and that these reactions take place in rarefied atmospheres of the rare gases. High potentials are needed, and helium gas seems to answer best. Those are not encouraging features for the technical outlook; but the rare gases are not so very rare after all, and they have proved useful already in various ways. The cheaper argon can also be used at lower potentials and higher gas pressures than helium.

Prof. Skaupy refers to one problem that might be solved by this method, the separation of neon into the two constituents of atomic weights 20 and 22, which Sir J. J. Thomson assumes to exist on the ground of his positive-ray analysis. Before the war Mr. J. W. Aston was engaged in the Cavendish laboratory in very laborious experiments for isolating the two constituents by means of many fractionations and diffusions. We do not know whether these experiments have since led to any definite result. But another point, not mentioned by Prof. Skaupy, occurs to us. When the discharge is sent through vacuum tubes supposed to contain one gas only, the glows at the two electrodes look different, and they change somewhat as the discharge continues. Those differences and their variations might partly be due to the presence of impurities and to the gradual demixing of the constituents which the gas undergoes during the discharge. In the case of neon the distinction would be difficult if the two neons have the same spectrum, as Aston believed.—*Engineering.*

Experiments on Earth-Pressures

By Ponsonby Moore Crosthwaite, B.A.I., M.Inst.C.E.

THE paper commences with a short account of Rankine's theory of earth-pressure, and the principles and assumption on which it is founded. Descriptions of former investigations are given in some detail, namely, those of the late Sir George Darwin, and Messrs. Goodrich, Wilson, Bell and Meem. The author concludes that of the experiments made by these investigators to investigate the lateral pressure of earth, those in which model walls were used are of greatest value, but points out that if models are of any size the experimental difficulties are almost insuperable.

The author's experiments, a number of which are described and illustrated in the paper, were made by loading a plunger with known weights and measuring the penetration when the plunger had come to rest after the application of each weight. The materials were enclosed in an open bucket, and their weight was determined.

With those data the value of ϕ, the angle of internal friction, can be obtained from Rankine's well-known formula for the safe depth of foundations:

$$d = \frac{P}{W}\left(\frac{1 - \sin\phi}{1 + \sin\phi}\right)^2$$

when d denotes the penetration; P the pressure in pounds per square foot; and W the weight of the material in pounds per cubic foot.

If the formula is true, and the pressures be plotted against the penetrations, the resulting curve is a straight line, and ϕ as calculated from the formula should equal the angle of repose.

With sand, garden earth, and cinders and ashes the resulting curves are straight lines, but it was found that the value of ϕ varied with the state of aggregation of the material, i. e., whether it was lightly poured into the bucket, shaken in, or well pounded in. When the material was deposited in the bucket as ligthly as possible the angle of internal friction was the same as the angle of repose, but with more consolidation the angle was much greater.

From these materials the author concludes that Rankine's theory holds, provided the proper angle of internal friction is used and not the angle of repose. If, however, this angle is used it would be necessary to introduce a factor of safety into the formula, for a wall designed without one would be theoretically just strong enough and no more. In Rankine's formula there is no factor of safety, and it is concluded that Rankine saw this, and used the angle of repose as covering the worst conditions that need possibly be provided for. The author's experiments show that, for the materials tested, work designed by Rankine's formula, using the angle of repose, would have a factor of safety of 2½ to 4, and he considers that these are not unreasonable figures for such materials.

The experiments on clay give altogether different results, for instead of the penetration varying as the load, it varies as the square of the load, and the penetration curves are parabolas. These results, which were altogether unexpected, are completely confirmed by larger experiments carried out by Messrs. Coode, Matthews, Fitzmaurice and Wilson, and by Mr. McAlpine in New York.

The author is able to give no physical explanation as to why the penetration in clay should vary as the square of the load, but leaves it to the physicists. The law must be capable of some rational explanation, and, if true, it upsets all earth-pressure theories when they are applied to clay; for all accepted theories assume that the angle of internal friction is the same as the angle of repose, and that its value is independent of the pressure.

It is suggested that the subject is worthy of further investigation, but that such could hardly be made by a private individual, for the work is tedious, each experiment taking from twenty-four to forty-eight hours. Moreover, if the investigation is to be properly carried out, physical and chemical analyses of the clays will be required that could only be made in a well-equipped physical laboratory.

In connection with the earth slides experienced at the Panama Canal, it has been suggested that in clay and shale cuttings there is a critical depth beyond which the sides will not stand, and the author's experiments on clays clearly show that for these this must be the case. Where ϕ is independent of the pressure the depth of the cutting cannot affect the stability of the slope, but where the angle decreases with the pressure it is evident that eventually a depth will be reached beyond which its sides will not stand.

This decrease is clearly shown in one experiment on mud, for which the angle for a pressure of 0.25 ton per square foot was 17 degrees 15 minutes, which decreased to 2 degrees 10 minutes at a pressure of 1.5 tons per square foot, when it was little better than a liquid.—*Abstract of a paper read before the Institution of Civil Engineers, in Engineering.*

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Table of Contents